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STUDIES UPON THE RELATIVE MERITS OF SWEET CORN VARIETIES FOR CANNING PURPOSES AND THE RELATION OF MATURITY OF CORN TO THE QUALITY OF THE CANNED PRODUCT[1]

By C. W. CULPEPPER and C. A. MAGOON, *Office of Horticultural Investigations, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

The market value of a canned food is determined primarily by its quality. Any factors, therefore, which affect the quality of a product deserve careful study to the end that a high standard of excellence may be established and consistently maintained. In the canning of sweet corn the variety factor, together with climatic considerations, has been regarded as of great importance in determining the quality of the finished product, and certain varieties have been thought by some to be exceptionally desirable for canning. This fact has had no small influence in directing the progress of corn canning both as a home and a commercial enterprise. Many kinds of sweet corn are grown in this country and a considerable number of them are being canned. It has seemed desirable, therefore, to subject the more widely known of these to careful comparative study to learn the importance of variety as a factor in canning quality.

Since certain factors other than varietal differences in the corn are known to affect the quality of the canned product, as for instance, the stage of ripeness, the promptness in handling after plucking from the stalk, etc., it was thought wise to give particular attention also to some of these matters and to record such related data as the conditions of the experiment permitted. This report, therefore, will be found to deal with matters of interest not only to growers and canners of corn but also to those who are interested in the physical development of the corn and in the chemical transformations taking place during the growing and maturing of the ear.

REVIEW OF LITERATURE

Sweet corn was first grown specifically for canning purposes about 1842, when Isaac Winslow, the pioneer in corn canning, arranged with his brother-in-law Caleb Jones, "to plant a piece of green corn for experimental purposes" (*18*).[2] It was 10 years later, however, before corn canning was well established, though an invoice of sale of canned corn as early as 1848 is on record.

The first comprehensive study of sweet corn seems to have been made by Salisbury (*54*) in 1849. This writer made observations upon 20 varieties of corn, including sweet, pop, dent, and flint varieties. He kept careful notes upon their characteristics as shown in the field and recorded the results of numerous chemical analyses made during the growth of the corn. In 1885, apparently receiving more or less inspiration from the work of Salisbury mentioned above, Körnicke and Werner (*35*) in their volumes upon the cereal grains discussed in considerable detail the subject of corn varieties.

[1] Received for publication Mar. 11, 1924.

[2] Reference is made by number (italic) to "Literature cited," p. 440-443.

The establishment of the State agricultural experiment stations in 1887 seems to have greatly stimulated studies upon corn, and during the next 10 or 12 years numerous papers were issued from different States dealing with various phases of the subject. These had to do with field observations upon the physical characteristics of the plants, earliness and lateness in maturing, yields, etc., with the taxonomy and description of varieties, the character and proportions of the various chemical constituents of the grain, the transformations in chemical composition during growth, breeding experiments, etc. It is manifestly impossible at this time to review all this work in detail and references to the literature will be confined, for the most part, to those papers dealing primarily with sweet corn.

Among those who have made more or less careful field studies upon sweet corn varieties may be mentioned Burrill and McCluer (*12, 13*), Butz and Baldwin (*16*), Latta (*36*), Taft, Coryell, and Gladden (*67*), Munson and Gould (*42*), Butz (*15*), Taft, Gladden, and Hedrick (*68*), Gould (*26, 27*), Rane (*48*) and Price and Drinkard (*47*). A brief taxonomic grouping of sweet corn varieties based upon careful field observations was made in 1890 by Burrill and McCluer (*13*) and in 1899 Sturtevant (*66*) prepared a monograph dealing with some 800 varieties in which an attempt was made to place the nomenclature upon a sound scientific basis. This monograph is regarded as the best treatment of the subject ever undertaken and is recognized as a standard work.

The literature bearing upon the breeding of sweet corn for the last 30 years has been confined largely to the genetics of the subject. Little has been written concerning the improvement of strains and the production of new varieties. However, this does not mean that such work has not been done but rather that the investigators have failed to record their results. Advance in this work has been made along three lines, namely, the development of superior varieties by hybridization, improvement by careful selection of existing strains, and the development of first-year hybrids from pure self-fertilized strains. The first has resulted in new types with respect to color, arrangement and size of grains, improved yields, etc.; the second, by use of the ear-to-row or "remanent" method, has yielded superior strains with respect to size and number of ears, etc.; and the third promises much in the way of uniformity of ears and yields.

For many years the practical breeding and selection of improved varieties of sweet corn have been largely in the hands of commercial seedsmen, though several of the State agricultural experiment stations are continuing work along this line.[1] Among those who by their early studies contributed materially to the success of later workers in this field may be mentioned Beal (*6, 7, 8, 9*), Ingersoll (*32*), Sanborn (*55*), McCluer (*38*), Morrow and Gardner (*40, 41*), Williams (*72*), Shull (*58, 59*) and East (*21*). The late Dr. W. W. Tracy, sr., of this office, whose breeding studies were never put into printed form, was likewise a potent factor in the development of improved strains. Reference to papers upon more recent investigations will be made in the discussion of results of the present study.

The chemistry of corn is a subject that has engaged the attention of many workers. Gorham (*25*), as far back as 1821, during his studies upon the composition of corn, discovered zein as one of the chemical constituents of the kernel, and Bizio (*10*) discovered the presence of oil. Boussingault (*11*) made determinations of the nitrogen content and pointed out the possibility of variations in the chemical constituents of the grain as being due to climatic factors. Horsford (*31*) reported complete ultimate analyses. Salisbury (*54*) whose comprehensive study has already been cited, was followed by a number of European workers,

[1] Work upon sweet corn improvement is being done at stations in Georgia, Wisconsin, Maine, Ohio, Connecticut, Iowa, Maryland, Indiana, Louisiana, New York, and other States.

including Polson (*46*), Poggiale (*45*), Stepf (*61*), Fresenius (*24*), and by Jackson (*33*) in this country, who studied the chemistry of the corn kernel. With the exception of Salisbury, however, the work of these early investigators was concerned with field varieties only. Atwater (*5*) in 1869 reported the results of analyses upon several varieties of corn, including one of sweet corn.

Hornberger (*30*) in 1882 added materially to the literature upon the chemistry of corn by publishing a very comprehensive paper, giving special attention to the chemical history of the plant during growth. While this work was done upon a single variety of field corn (Badische Frühmais, Poppelsdorf 1878) it opened up a very important field of research which has not yet been completely covered. In 1883 Richardson (*50*) published the results of investigations upon wheat and corn in which are compiled the analyses of 19 samples of sweet corn derived from various sources, and again in 1884 (*51*) figures upon 4 others were placed on record. Flechsig (*23*) in 1886 made analyses of 14 different varieties of corn, including one sweet variety. Schweitzer (*56*), following the same line of investigations as Hornberger, in 1889 reported upon a study of the life history of corn at its different periods of growth, using the St. Charles White as the source of his material. In the same year Failyer and Willard (*22*) reported upon analyses of King Philip and Yellow Dent corns at different stages of growth, and Washburn (*70*) published his results upon the changes in chemical composition of sweet corn during the ripening processes.

Further work upon the chemistry of the corn kernel was reported by Maynard (*39*), but his analyses were based upon air-dried material, hence the figures are difficult of comparison. Chittenden and Osborne (*17*) gave special attention to the proteins of the kernel, and later on Osborne and Clapp (*44*) carried the investigation of the proteins still further, making special study of the amino acids resulting from hydrolysis. The characteristic proteins in high and low protein corn have been more recently considered by Showalter and Carr (*57*). The Report of the Connecticut State Agricultural Experiment Station for 1893 (*19*) recorded the results of analyses upon 90 samples of corn kernels and pointed out the relation of climatic and soil factors to the chemical composition of the grain. Stone (*63*) in his study of the carbohydrates from various materials considered somewhat those of maize, but feed varieties only seem to have been examined. Hopkins (*29*) went rather carefully into the chemistry of the corn kernel and in addition to a critical review of the literature recorded the results of his own studies upon the constituents of corn, giving special attention to the oil. The major portion of this work, at least, seems to have been done upon a single variety of field corn (Burr's White) and apparently nothing was done upon sweet varieties.

Of very great interest and importance to the present work is that which was reported by Straughn (*64*) in 1907. The object of this work as stated by the writer was to assist in the breeding of superior sweet corn for table and canning uses. He found that so constant and uniform was the sugar of the mature grains that it was not feasible to select for high sugar content from the dry kernels. The wrinkling of the kernel seemed to bear some relationship to the sugar content, however, the finely wrinkled grains having a slightly higher sugar content than the more coarsely wrinkled. Of particular importance in this work was the finding that the sugar content of the corn in edible condition alters rapidly during the first few hours after the ears are plucked from the stalk. Further studies upon the transformations occurring in green sweet corn during storage at different temperatures were reported by Straughn and Church (*65*) in 1909. Losses in sugar and deterioration in flavor were noted at all temperatures and their conclusions were summarized in the statement that corn should be put on the market or canned with as little delay as possible after gathering.

This work, so well begun at the Maryland State Experiment Station, has been continued and during the last few years several papers have appeared which have gone further into the subject and added materially to the solution of the corn canning problem. Thus, Appleman and Arthur (*2*) have reported upon carbohydrate metabolism in green sweet corn during storage at different temperatures. These workers followed the rate of loss of sugars and found that the loss was doubled for every increase of 10° up to 30° C., until it reached 50 per cent of the initial total sugar and 60 per cent of the sucrose. The rate of loss was slower beyond that point. They found this loss in sugar to be effected in small part by respiration but primarily by its condensation into polysaccharides, chiefly starch. The importance of respiration which causes the inside heating of large piles of corn as being responsible for losses of sugar was emphasized. Similar results were obtained by Stevens and Higgins (*62*) who conducted studies upon sweet corn grown in both Maryland and Maine. In 1921 Appleman and Eaton (*3*) published upon the evaluation of climatic temperature efficiency for the ripening processes in sweet corn, recording considerable analytical data showing changes in the composition of corn during the ripening period, and predicting the average expectations as to the time between premilk and best edible milk stage, and the length of time in the best edible stage for different ripening seasons in various Eastern States. This valuable work would have been much more so if the exact age of the ears at the various sampling dates had been known. The same year Appleman (*1*) recorded experiments designed to determine the reliability of the nail test for predicting the chemical composition of green sweet corn. It was found that the reliability of the test was influenced by the rate of ripening and the rate of water loss by evaporation, the test being most reliable when applied to crops which ripen slowly in the cool autumn.

This brief survey of the literature is not intended as a complete discussion of all the valuable work that has been done upon corn but rather as showing the nature and scope of it. It is impossible in a paper of this size to discuss in detail the work of more than a few writers. It is believed, however, that the work cited fairly represents the nature and quality of what has been done along these lines. More specific reference will be made to these and other papers in the discussion of results of the present investigations. In reviewing these papers it is seen that the taxonomy of sweet corns has received considerable attention, the behavior of the different varieties under field conditions has been widely studied, and the selection and breeding of improved varieties have reached a point of scientific accuracy. The organic and mineral constituents of the kernel have been investigated by numerous workers, and an attempt made to follow through chemically the life history of the corn. The relation of temperature and other factors to the ripening of the corn, and the effects of storage upon table qualities have been the subject of careful research. A comprehensive study of sweet corn varieties from the standpoint of their desirability for canning purposes, however, seems never to have been attempted, and several matters of fundamental importance to corn canning have not yet been fully investigated. No basis seems to have been worked out for determining the relative merits of different varieties, and just what constitutes quality is but vaguely understood. The fundamental differences between field and sweet varieties as affecting canning quality, though perhaps appreciated, have never been submitted to careful investigation. Much still remains to be done upon the history of the chemical transformations undergone during the development of the ear and no more accurate field method for the determination of maturity of the corn has yet been devised than the actual "rule of thumb" method known as the nail test. The relation of meteorological and other climatic or regional factors, while recognized, have not been sufficiently investigated.

These and related considerations have led to the present investigations, and these data are presented in the hope that they may be of assistance in solving some of the problems of corn canning.

EARLY INVESTIGATIONS

The experimental work upon which this report is based was begun in 1919 when a number of the leading varieties of sweet corn were tested for the comparative merits of their canned product. The corn was grown especially for the work at the Arlington experiment farm, Virginia. When sufficiently mature, the ears were plucked in what was considered prime canning condition, and removed at once to the laboratory where the corn was immediately prepared for the can. Uniform canning methods were followed throughout the whole experiment so that the canned products were entirely comparable. Shortly after the end of the season these canned corns were subjected to critical comparative study with respect to appearance, flavor, and general table qualities, and the results placed on record for future reference in connection with later experiments similarly conducted.

During the season of 1920 the work was repeated, using a somewhat larger number of varieties. Upon critical examination of the cut-out material of this pack, however, it was found that although the corns had been grown under as nearly identical conditions as possible, and the same canning methods had been followed, the corns graded entirely differently from those of the preceding season. For instance, Country Gentleman which graded "first" in the 1920 pack held third place the previous year, and Golden Bantam which was given first place in 1919 yielded to Charlevoix in 1920. Other varieties also held different relative positions.

Reserve stocks of the 1919 pack were then opened for comparison with the corns canned in 1920, and the packs subjected to careful study to determine what the nature of the differences were, and to learn, if possible, the reasons for the same. The conclusion arrived at was that some factor or factors other than varietal differences determine to a large extent the quality of the canned corn. The most prominent factor seemed to be that of maturity of the corn at the time of harvesting which affected the condition of the carbohydrates, the delicacy of flavor, and the toughness of the kernel. It was thought also that climatic or seasonal factors might be responsible in part, and possibly also the soil conditions. It was apparent that here was a very important problem which needed thorough study.

Pressure of work upon other investigations prevented the carrying forward of this work during the 1921 season.

WORK OF 1922

In the spring of 1922 plans were laid for the study of the problem upon a more comprehensive scale, the object being to correlate varietal, maturity, and other factors involving the quality of the canned product, and to bring to light any significant facts previously neglected or overlooked. The plan called for the study of all the important varieties used for canning purposes, under, as nearly as possible identical conditions as regarded climate, soil and cultivation, and field and laboratory technique. No attempt was made to investigate the relation of fertilizer and soil factors to the problem but meteorological and other environmental factors were studied so far as data in regard to them could be obtained.

The varieties studied included both white and yellow sorts and comprised early, medium and late maturing corns. These, given in approximately the order of maturing, were: Of the white sorts, Howling Mob, Crosby, Hickox's Improved, Potter's Excelsior, Kelly's Hybrid, Mammoth Sugar, Old Colony, Narrow Grained Evergreen, Country Gentleman, and Stowell's Evergreen; and of the yellow, Golden Bantam, Dreer's Golden Giant, Charlevoix, Morse's Golden

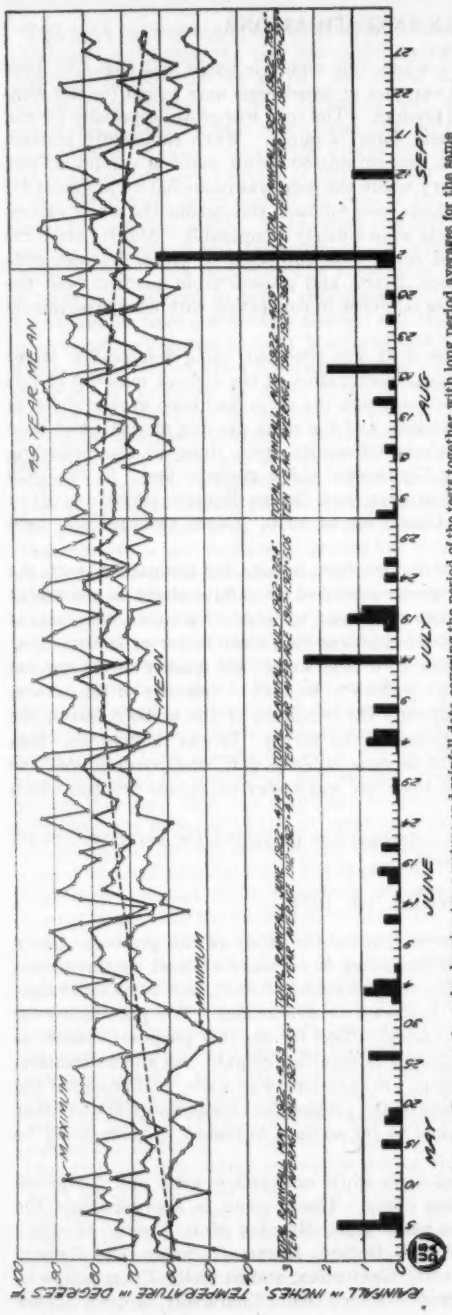

FIG. 1.—Curves and graphs showing temperature and rainfall data covering the period of the tests together with long period averages for the same

Cream and Vaughn's Bantam Evergreen. Reid's Yellow Dent and Boone County White, two standard varieties of field corn, were grown along with the sweet varieties and these were studied for comparison with the sugar corns throughout the entire experiment.

Golden Bantam and Charlevoix of the yellow varieties and Howling Mob and Crosby of the white varieties were planted May 17, 1922. All the others were planted May 24, 1922. The soil was very uniform, deep, rich loam and the plots themselves level and well drained by an underground tile system. The kind and amount of fertilizer and the nature and amount of cultivation were the same for all plots. With the exception of Country Gentleman, which was more heavily seeded and later required thinning, the seeding was uniform for all and a good, uniform stand was obtained in practically all cases. The seed was purchased from commercial concerns which regularly supply the sweet corn growers and it is believed fairly represented that generally sold for canning purposes.

METHODS

In order that the samples of corn from the different plots might be strictly comparable it was essential that the material from ears of the same age only should be compared. Inasmuch as the appearance of the ear on the stalk had proved an unsafe criterion of age it was decided to tag each ear as the silk made its appearance. Every morning, therefore, between the hours of 9 and 12

throughout the flowering period each plot was carefully searched for all specimens showing the first appearance of silks, and tags bearing the respective dates were attached thereto. To facilitate the later gathering of sample ears of a given date tags of different colors were used on different days. This detail proved of great assistance in the rapid collection of samples. Careful records were kept of each day's tags so that the rate of silking and the length of the silking period of each variety were known, and data were at hand to tell when sufficient material was available for the various tests.

Samples were taken for canning tests at the ages of 15, 20, 25, and 30 days, and samples for chemical analysis were taken at the ages of 5, 10, 15, 20, 25, and 30 days.

Since the behavior of varieties and the chemical composition of samples is affected by climatic factors data upon temperature and rainfall are given in the accompanying chart which shows the conditions under which the corns were grown. Complete temperature records covering the test period were not obtainable at the Arlington experiment farm as only maximum and minimum daily temperatures were recorded. The figures given are those obtained from the United States Weather Bureau at Washington whose station is situated but a short distance across the river from the Arlington farm. Careful comparison of the records from the two sources have shown that differences in temperature in the two places were too small to be of significance. In most cases the temperatures were practically identical, and the data given, therefore, may be considered as fairly representing the actual temperature conditions under which the corn was grown. The data upon rainfall were obtained at the Arlington farm.

Examination of the chart shows that the mean daily temperature for the growing and maturing period of the corns under study was somewhat above the 49-year average during May and June, but fairly close to it during July. August was somewhat below the average.

Taken as a whole, the season was rather wet, there being an excess of 3¾ inches of rainfall for the months May to August, inclusive. The excessively heavy downpour of September 2, while occurring before all the samples were harvested, had little if any effect upon those remaining to be handled since they were well along toward maturity at this time. It will be noted that the rainfall was well distributed throughout the test period. While several rather heavy rains occurred, in no case was there a drowning of the corn as the underground drainage system rapidly removed all excess of moisture.

It is regretted that data upon soil temperatures and moisture content of the test plots are not available for presentation in this connection.

EXPERIMENTAL RESULTS

THE SILKING PERIOD

The significance of the silking period of corn as a practical aid in determining when and how rapidly a field of corn would come to canning maturity seems never to have been appreciated, but the fact that the quality of the canned product is intimately associated with the stage of ripeness of the corn when it goes into the can makes the consideration of this matter of importance. Burrill and McCluer (*12*, *13*) in studies upon a considerable number of varieties noted the date of the first bloom, the date of the full bloom and that when the corn was first fit for use. Butz and Baldwin (*16*) recorded the date of tassel and the dates of the first and last ears upon a number of varieties including Crosby, Mammoth Sugar, and Stowell's Evergreen. Munson and Gould (*42*) observed the dates of the first appearance of tassels, the appearance of silks and of edible maturity upon 15 varieties of sweet corn, and Gould (*26*, *27*) gave like data for the two succeeding years upon 25 varieties. Butz (*15*) recorded the date of tassel and the date of the first and of the last ears. Kiesselbach (*34*) in investigations upon field corn gave attention to the length of the period of pollination, the life of the pollen and the life of the silk; and in the tabulation of results of his experiments has shown the dates of tasselling along with the dates when the corns were ripe.

The methods followed in the collection of data upon the silking period in the present investigations made it possible to study this subject in a more comprehensive manner than has been hitherto attempted, and inasmuch as these data show the relative earliness of the different sweet corns under study, the rate at which each of the test plots came into flower, the length of the silking periods for the different corns, to some extent also the relation of meteorological factors to the silking period, and various other factors, they have been arranged in graphic form in Figure 2 which is presented herewith.

An error of minor importance in this chart exists with respect to relative earliness in the case of Golden Bantam, Crosby, Charlevoix, and Howling Mob which, as stated before, were planted on May 17, one week earlier than all the others. These graphs are based upon the actual dates of appearance of silks regardless of the date of planting; but Latta (*36*) has shown that in Indiana a difference of one week in planting at this season makes a difference of about 5 days in the time of maturing, that planted earlier requiring longer to mature. The amount of correction to apply for this factor in the present case is impossible to determine accurately as no check was secured upon this point. The change in relative positions of these varieties would be small, in any case making them but one or possibly two days later than indicated on the graphs.

It will be seen that even after taking into consideration the correction just mentioned, Golden Bantam was the earliest of all the varieties tested, the first silks appearing on July 3 and the maximum silking being reached just one week later. Howling Mob was earliest of the whites. It first showed silks on July 8, and the high point of its silking period was 5 days later. Vaughn's Bantam Evergreen was the latest of the yellow varieties, its first silks appearing on July 14. Maximum silking in this variety took place about 10 days later. The Evergreens and Country Gentleman were the latest of the whites. The latter which began silking one day later than Stowell's Evergreen showed its first silks on July 21, and on July 28 the highest number were recorded. Both varieties of Dent Corn were later than any of the sweets, and Boone County White considerably so. It began silking on July 30 and reached its maximum about one week later.

In the presentation of data later on in this report it will be shown that the rate at which a field of corn comes into flower and the length of the silking period make it possible to estimate with considerable accuracy when the corn will be ready for canning and how long the canning season for that field is likely to be. Of special interest therefore, are these figures as illustrating this point. For example, it will be seen by the figures for Golden Bantam and Howling Mob that these plots came into silk very rapidly and the periods during which abundant silking occurred were brief. This indicates that the bulk of these corns would come to edible or canning maturity during a few days only and the canning season would be correspondingly short, which proved to be true. The figure for Potter's Excelsior, on the other hand, shows that the period during which abundant ear formation was taking place was much longer, and indicates that ears for table and canning purposes could be secured over a considerable period of time, which likewise was found to be the case.

A variety of factors may influence results of this sort and therefore too much importance should not be attached to a single set of experiments. The use of inferior seed, difference in cultural practices, meteorological conditions, and other factors may be responsible for certain variations in rate of silking and the length of the silking period, and it is possible that one or more of these were responsible for some of the irregularities showing in these graphs.

Attention is called particularly to the depression in the figures for the dates of July 15 and 27, respectively. Reference to the chart on temperature and rainfall will show that during the 24 hours preceding each of these dates there was a distinct drop in temperature, and in the case of the earlier date this fall in temperature was accompanied by heavy rainfall.

It is believed that comparable tests of this sort made in the different sweet-corn producing sections of the country would not only be of value to those in-

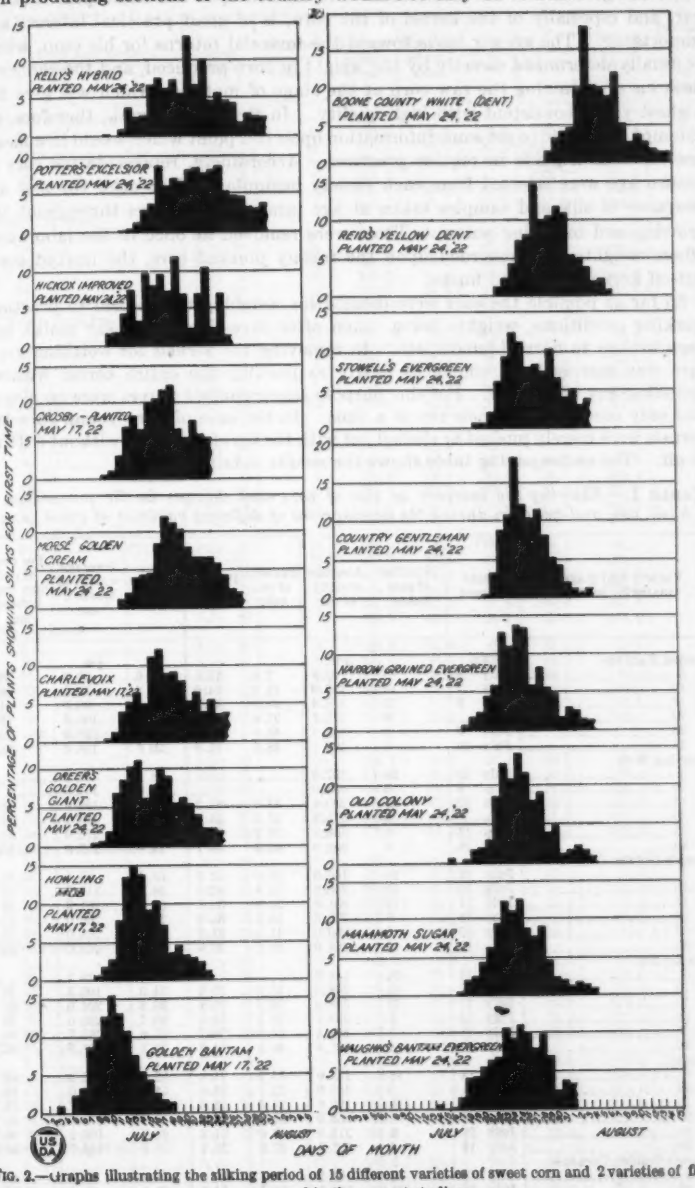
KELLY'S HYBRID PLANTED MAY 24, '22
POTTER'S EXCELSIOR PLANTED MAY 24, '22
HICKOX IMPROVED PLANTED MAY 24, '22
CROSBY - PLANTED MAY 17, '22
HORSE GOLDEN CREAM PLANTED MAY 24, '22
CHARLEVOIX PLANTED MAY 17, '22
DREER'S GOLDEN GIANT PLANTED MAY 24, '22
HOWLING MOB PLANTED MAY 17, '22
GOLDEN BANTAM PLANTED MAY 17, '22
BOONE COUNTY WHITE (DENT) PLANTED MAY 24, '22
REID'S YELLOW DENT PLANTED MAY 24, '22
STOWELL'S EVERGREEN PLANTED MAY 24, '22
COUNTRY GENTLEMAN PLANTED MAY 24, '22
NARROW GRAINED EVERGREEN PLANTED MAY 24, '22
OLD COLONY PLANTED MAY 24, '22
MAMMOTH SUGAR PLANTED MAY 24, '22
VAUGHN'S BANTAM EVERGREEN PLANTED MAY 24, '22
PERCENTAGE OF PLANTS SHOWING SILKS FOR FIRST TIME
JULY
AUGUST
DAYS OF MONTH
USDA

FIG. 2.—Graphs illustrating the silking period of 15 different varieties of sweet corn and 2 varieties of field corn used in the present studies

terested in the canning of the corn but also would throw light upon the relation of latitude, temperature, and other seasonal factors to the growing of the corn, and the selection of desirable varieties.

DEVELOPMENT OF THE EAR

To the grower and the canner alike information upon the development of the ear, and especially of the kernel of the corn, is of great practical interest and importance. The grower looks toward the financial returns for his crop, which is usually determined directly by the weight of corn produced, and the canner is desirous of obtaining the raw corn at the stage of maturity which will give the highest yields consistent with high quality. In the present work, therefore, an attempt was made to get some information upon this point which would in a measure serve as a guide in regular practices. Accordingly, representative ears of known age were selected from each variety beginning 5 days after the first appearance of silk and samples taken at age intervals of 5 days throughout the growing and maturing season. These were removed at once to the laboratory where weights were recorded upon the freshly plucked ears, the husked corn, cut-off kernels, cob, and husks.

So far as possible the ears were dressed for weighing to conform to practical working conditions, weights being taken after excessively long ear stalks had been broken to normal length, etc. In removing the kernels for weighing great care was exercised to remove as nearly as possible the entire kernel without including any of the cob. For this purpose sharp pointed knives were employed and only one row of kernels cut at a time. In the case of very young corn the kernels were merely pushed or shelled out with the tip of the blade without cutting at all. The accompaying table shows the results obtained.

TABLE I.—*Showing the increase in size of ears and changes in the proportion of husk, cob, and cut corn during the development of different varieties of sweet corn*

Variety and stage of maturity in days	Date tagged	Number of ears taken	Average weight of ear	Per cent of cut corn	Per cent of cob	Per cent of husk	Average weight of husked ear	Per cent of cut corn from husked ear
Golden Bantam:	1922		*gm.*				*gm.*	
5	July 8	10	91.8	7.8	17.5	74.6	23.3	30.7
10	July 7	15	152.0	12.2	34.0	53.7	70.3	26.3
15	July 6	11	155.4	25.9	31.9	42.1	90.0	44.7
20	do	9	176.1	27.4	29.6	42.9	100.5	48.0
25	July 7	8	187.5	46.6	21.0	32.3	126.9	68.9
30	July 11	6	194.1	48.5	21.8	29.6	136.6	68.8
Howling Mob:								
5	July 12	24	137.5			64.5	48.9	
10	July 8	5	284.0			52.8	134.0	
15	July 12	11	280.4	23.9	43.5	32.5	189.5	35.4
20	do	6	275.8	35.3	33.2	31.4	189.1	51.5
25	July 13	6	355.0	39.2	36.8	23.9	270.0	51.5
30	July 18	5	346.0	45.3	34.7	19.9	277.0	56.6
Dreer's Golden Giant:								
5	July 13	19	140.0	11.0	23.5	65.4	48.4	31.9
10	July 10	10	240.5	10.8	34.9	54.2	110.2	23.6
15	July 11	13	251.1	24.8	39.6	35.5	161.9	38.5
20	July 13	6	278.3	36.8	35.0	28.1	200.0	51.2
25	July 17	6	280.0	41.9	31.2	26.8	205.0	57.3
30	July 19	5	338.0	50.5	26.9	22.5	262.0	65.2
Charlevoix:								
5	July 12	24	141.3			79.3	29.1	
10	July 11	11	238.6	16.0	29.9	54.0	109.5	34.8
15	July 17	10	338.0	28.5	31.8	39.6	204.0	47.3
20	July 14	6	339.1	36.1	33.1	30.7	235.0	52.1
25	July 18	7	408.5	46.6	25.7	27.6	295.7	64.4
30	July 15	6	345.8	49.8	24.6	25.5	257.5	66.9
Crosby:								
5	July 13	18	113.0	15.9	21.6	62.4	42.5	42.2
10	July 11	6	180.9	22.4	32.8	44.7	100.0	40.6
15	July 12	12	192.9	21.5	42.6	35.8	123.7	33.7
20	July 14	6	255.0	37.2	29.4	33.3	170.0	55.8
25	July 21	8	212.5	47.0	31.2	21.7	166.2	60.0
30	July 19	4	227.5	47.8	26.3	25.8	168.7	64.4
Morse's Golden Cream:								
5	July 14	24	101.2	11.4	12.6	75.9	24.3	47.6
10	July 15	15	164.0	16.5	32.8	50.6	81.0	33.4
15	July 12	10	201.0	25.6	30.3	44.0	112.5	45.7
20	July 19	7	257.1	43.6	22.2	34.1	169.2	66.2
25	July 22	8	221.9	48.4	23.6	27.9	160.0	67.1
30	July 23	7	216.5	57.0	26.1	16.8	180.0	68.6

TABLE I.—*Showing the increase in size of ears and changes in the proportion of husk, cob and cut corn during the development of different varieties of sweet corn*—Continued.

Variety and stage of maturity in days	Date tagged	Number of ears taken	Average weight of ear	Percent of cut corn	Percent of cob	Percent of husk	Average weight of husked ear	Per cent of cut corn from husked ear
Hickox's Improved:	1922		Gm.				Gm.	
5	July 14	25	116.6	14.3	17.7	67.9	37.4	44.8
10	do	14	175.3	16.2	37.3	46.4	93.9	30.2
15	July 16	10	265.0	20.7	42.1	37.1	166.5	33.0
20	July 18	7	274.2			33.3	182.9	
25	July 20	6	310.0	36.5	32.3	31.1	213.3	53.1
30	July 22	5	243.0	41.1	41.2	17.5	200.0	50.0
Kelly's Hybrid:								
5	July 14	17	154.7	14.1	19.1	66.7	51.4	42.4
10	July 15	15	188.0	18.0	37.6	44.3	104.6	32.4
15	July 19	6	338.3	19.2	43.3	37.4	211.6	30.7
20	July 21	5	345.0	30.4	37.9	31.6	236.0	44.4
25	July 27	6	420.9	44.9	32.8	22.2	327.5	57.7
30	July 24	6	315.0	48.9	31.7	19.3	254.1	60.6
Potter's Excelsior:								
5	July 16	12	189.1	13.7	14.3	71.9	44.5	49.1
10	July 17	12	227.9	17.7	42.9	39.3	138.3	29.9
15	July 18	6	339.1	25.3	37.8	36.8	214.1	40.0
20	July 21	6	352.5	28.6	34.0	37.3	220.8	45.6
25	July 24	5	345.0	45.2	30.7	24.0	262.0	59.5
30	July 26	6	376.6	46.9	30.5	22.5	291.6	60.5
Vaughn's Bantam Evergreen:								
5	July 19	21	143.3	16.3	19.5	64.1	51.1	45.5
10	July 21	10	240.0	16.4	37.0	46.5	128.5	30.7
15	July 20	6	290.0	29.3	36.5	34.1	190.9	44.5
20	July 22	6	339.1	39.3	29.4	31.2	233.3	57.1
25	July 24	6	327.5	50.8	21.9	27.2	238.3	69.9
30	July 26	6	400.0	55.0	24.5	20.4	318.3	69.1
Mammoth Sugar:								
5	July 19	18	148.0	19.8	23.4	56.7	64.1	45.8
10	July 21	10	379.0	13.4	40.8	45.7	206.0	24.7
15	July 24	6	465.0	21.6	41.7	36.6	295.0	34.1
20	July 23	6	508.3	30.0	34.5	35.4	328.3	46.4
25	July 25	6	441.6	43.5	31.5	24.9	331.6	56.0
30	July 27	5	498.0	49.0	28.1	22.8	384.0	63.5
Old Colony:								
5	July 20	14	163.5	19.6	21.8	58.5	67.9	47.3
10	July 19	9	251.6	16.5	39.5	43.9	141.1	29.5
15	Aug. 3	5	272.0	28.3	37.8	33.8	180.0	42.7
20	July 22	6	340.0	39.9	30.1	29.9	238.3	56.9
25	July 23	6	420.0	51.1	26.8	22.0	327.5	65.6
30	July 25	6	410.9	58.2	25.5	16.2	344.1	69.4
Narrow Grained Evergreen:								
5	July 20	15	164.3	18.5	22.4	59.0	67.3	45.2
10	July 21	11	228.1	18.9	41.7	39.3	138.1	31.2
15	July 25	7	394.2	27.7	40.5	31.7	269.2	40.5
20	July 23	6	340.0	43.6	33.0	23.3	260.9	56.8
25	July 28	6	494.1	54.4	23.9	21.6	387.5	69.4
30	July 22	6	435.0	59.9	22.4	17.6	358.3	72.7
Country Gentleman:								
5	July 22	27	103.1	20.6	21.5	57.8	43.5	48.9
10	July 23	12	191.6	21.9	38.0	40.0	115.0	36.5
15	July 25	10	216.0	29.4	41.4	29.1	153.0	41.5
20	July 26	10	253.5	46.1	29.6	24.2	192.0	60.9
25	July 23	10	257.0	55.8	26.4	17.7	211.5	67.8
30	July 24	10	216.5	60.7	24.0	15.2	183.5	71.6
Stowell's Evergreen:								
5	July 23	17	216.4	15.3	29.7	54.9	97.6	34.0
10	July 22	10	328.5	18.8	40.2	40.9	194.0	31.9
15	July 25	12	327.5	28.7	44.0	27.2	238.3	39.5
20	July 26	6	411.6	45.9	31.8	22.2	320.0	59.1
25	July 27	6	418.3	52.1	24.7	23.1	321.6	67.8
30	July 29	5	474.0	62.8	23.6	13.5	410.0	72.6
Reid's Yellow Dent:								
5	July 28	10	279.0	12.3	22.7	64.9	98.0	35.2
10	July 24	8	333.6	15.1	31.6	53.2	156.2	32.4
15	July 30	6	394.1	23.6	48.8	27.5	285.9	32.6
20	July 28	6	485.8	43.5	37.9	18.5	395.9	53.4
24	July 31	6	485.8	50.5	32.8	16.6	405.0	60.4
30	July 29	4	580.0	57.3	23.2	19.4	467.5	71.1
Boone County White:								
5	Aug. 3	10	189.0	10.3	20.9	68.7	59.0	33.0
9	Aug. 1	8	295.6	12.6	39.1	48.2	153.1	24.4
15	Aug. 8	6	405.0	18.7	41.5	39.7	244.1	31.0
20	Aug. 4	6	478.3	28.9	39.0	32.0	325.0	42.5
25	Aug. 5	4	520.0	38.2	32.2	29.5	366.2	54.2
30	Aug. 6	6	503.3	44.7	28.6	26.6	369.1	60.9

The outstanding feature of this table is the illustration of the fact that for the ear as a whole there is a progressive gain in weight throughout the growing period; that as a rule the cob shows its highest percentage weight at about 15 days from the first appearance of silks, after which it falls off; and that in general the kernels continue to increase in weight throughout the whole period, up to 30 days of age. This last fact is of particular importance as showing that if the highest quality of canned corn is to be produced the proper maturity must be considered as of more importance than highest yield.

It is indicated by these figures that under the conditions of the present experiment the heaviest yields of cut corn per ton of ears was produced by Country Gentleman and Stowell's Evergreen. Others which stood well from this standpoint were Morse's Golden Cream, Narrow Grained Evergreen, and Old Colony. Of the earlier corns, Crosby, Dreer's Golden Giant, and Charlevoix gave fair cuts, though these were considerably below Country Gentleman. The production from few-rowed varieties and from those having a disproportionately large ear was low.

Objection may be made to this table on the ground that too few ears were taken to make the figures truly representative of average conditions. The use of small numbers of ears was made necessary by the circumstances under which the work was done, but in the selection of ears for these tests an earnest endeavor was made to choose those ears which were truly representative of the whole and of the variety under study. While, therefore, slight irregularities may be noted in the progress of changes as indicated by these figures, it is believed that, taken as a whole, they give a fairly close approximation of actual average conditions.

TOUGHNESS OF KERNEL

Although flavor and consistency, or body, are important factors in determining the quality of canned corn, more and more it is coming to be realized that the tenderness or toughness of the kernel is of even greater importance. Immaturity is sometimes masked in the canned corn, in part at least, by the addition of starch, and too heavy consistency due to the use of overmature corn is often avoided by the use of a greater proportion of liquor; but general toughness can not be masked, and it is this more than anything else which unfavorably affects the quality of canned corn. This point has been emphasized by Burton (*14*), who states that "commercial grades of canned Country Gentleman corn, as far as they are concerned by maturity, differ only in the proportion of tough and tender kernels present."

Burton (*14*) undertook a study of the cause of increased toughness in overmature corn and sought a practical means of determining maturity. He reported that the hull of Country Gentleman corn did not thicken with increasing maturity, but that it did lose progressively in moisture. The crude fiber figure for the hulls alone was found to be nearly constant at all maturities. The results of his experiments indicated that the specific gravity of the kernels afforded a means of differentiation of old from young corn.

Remington (*49*) in his report of analyses of the canned product from Crosby, Country Gentleman, Evergreen, and Golden Bantam varieties recorded slight differences in the percentage of crude fiber in the varieties studied, and stated that in his experience the amount of fiber tended to increase with the maturity of the corn. From the data presented, however, it is impossible to judge of the amount of this tendency as the analyses were made of material secured from different sources and apparently without information as to the exact age of the corn when it was canned.

During the last few years a number of workers have made use of mechanical appliances in studies upon the maturity of various fruits and vegetables, the idea being based upon the fact that with increasing maturity alterations in the tissues occur which affect their resistance to pressure or penetration. Thus Rosenbaum and Sando (*52*) made use of a modified Joly balance equipped with a puncturing needle in studying the resistance of tomatoes to penetration, and Lewis, Murneek, and Cate (*37*) and Murneek (*43*) employed a mechanical puncturing device to determine the ripeness of pears. Rudnick and Bakke (*53*)

likewise made use of this idea in the study of the resistance to puncture of the pericarp of sweet corn as related to maturity and other factors, and reported an increase in the resistance of the pericarp to puncture with increasing maturity of the corn.

In laying out the plans for the present investigations it seemed to the writers that inasmuch as the toughness of the kernel is of great importance in determining the quality of the canned product from sweet corn a wider application of the puncture test could be made to advantage and that a more convenient and practical instrument could be made than had hitherto been employed. A simple direct-reading puncturing apparatus was therefore devised, and tests were conducted upon the different varieties of corn at 5-day intervals throughout the critical period. A diagram showing the features of this instrument is presented herewith.

This apparatus consists of a glass tube 13 inches long, having an internal diameter of $\frac{1}{4}$ inch and a plunger constructed of aluminum rod $\frac{3}{16}$ inch in diameter and 14 inches long, which is fitted with a small needle holder at the outer end, a thin square metal indicator at the other, and attached just below this indicator to a steel wire coil spring. This spring is made from No. 22 steel piano wire so coiled as to allow of extension and contraction without coming into contact with either the inner walls of the glass tube or the plunger passing through it at the center, and is attached on one end to the upper end of the plunger, as already described, and on the other at the lower end of the glass tube. The plunger is kept properly centered by means of the square metal indicator tip at the upper end, which moves sufficiently freely to make friction insignificant, and by a thin smooth metal guide at the bottom of the tube, which allows of free movement with minimum friction.[4] The needle consists of a piece of No. 16 brass wire,

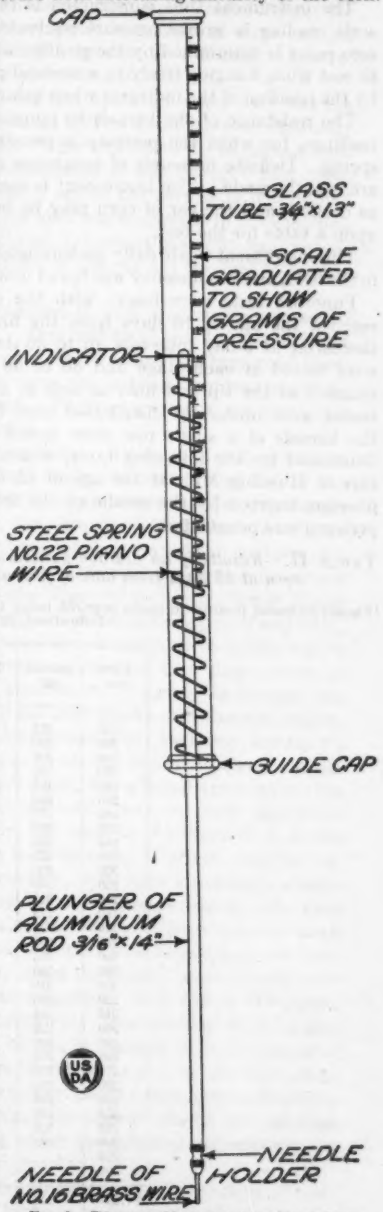

FIG. 3.—Diagram of instrument used in making puncture tests

[4] Numerous trials were required to secure the proper length and extension of the spring. It was essential that the spring be so constructed and adjusted as to operate satisfactorily without fatigue within the effective range of the tube, and to meet the needs as regarded the resistance of the kernels to puncture. It was likewise necessary that the spring be sufficiently sensitive to make the readings of resistance clear-cut and accurate. This condition was satisfactorily attained in the apparatus described.

three-fourths inch long, the tip of which is carefully squared to right angles with the axis.

The instrument thus constructed is carefully standardized and a graduated scale reading in grams pressure equivalents placed upon the glass tube. The zero point is determined by the position of the indicator when the plunger comes to rest while hanging freely in a vertical position. Other points are determined by the position of the indicator when balancing the proper corresponding weights.

The resistance of the kernels to puncture is determined by clear-cut positive readings, for when the pericarp is penetrated there is a sharp reaction of the spring. Definite measures of toughness of kernels on different parts of the ear are rapidly made. The instrument is easily operated by the right or left hand, as desired, and the ear of corn may be held either in the other hand or placed upon a table for the test.

This instrument was in daily use throughout the season both in the laboratory and in the field, and its efficiency was found unimpaired at the conclusion of the work.

Puncture tests were begun with the different varieties when the ears had reached the age of 10 days from the first appearance of silk and were made thereafter at 5-day intervals up to 30 days. From 3 to 5 representative ears were tested at each stage and 30 to 40 kernels on each ear, including those situated at the tip and butt as well as at the middle of the ear. The kernels tested were uniformly distributed over the whole ear though occasionally all the kernels of a single row were tested. The results of an average test are illustrated by the following table, which shows the readings obtained upon 4 ears of Howling Mob at the age of 15 days. The figures represent grams of pressure exerted by the needle of the instrument upon the kernels before the pericarp was penetrated.

TABLE II.—*Results of an average puncture test upon 4 ears of Howling Mob sweet corn at 15 days from date of first appearance of silks on these ears*

[Figures represent pressure in grams required before the needle penetrated the pericarp of the kernels. Date of test, July 27, 1922]

First ear	Second ear	Third ear	Fourth ear
220	215	210	200
220	235	220	180
240	205	250	180
230	185	230	220
180	195	225	245
230	230	230	220
240	175	210	200
250	230	260	195
210	225	270	195
210	225	185	160
200	220	225	200
230	240	220	190
235	215	260	210
180	175	230	190
220	195	240	210
280	260	220	180
200	255	255	220
200	240	235	210
200	210	270	205
220	225	200	220
210	185	235	205
240	220	200	195
220	210	210	200
225	210	215	180
270	210	250	180
220	230	275	230
210	230	220	195
255	180	230	235
235	205	215	205
200	195	190	180
210	------	------	210
190	------	------	205
Av. 221	214	230	201

Grand average, 216.

These results are typical of those obtained with all varieties, though in some instances greater differences in the range of toughness of individual kernels were observed, as well as, occasionally, greater differences in the averages for the test ears. On the whole, the results of these tests showed clear-cut and significant differences in the toughness of the kernels at different stages of maturity, as will be shown by the curves which follow shortly.

What was at first a surprising result in the test upon individual ears was the finding that the kernels at the butt of the ear as well as at the tip were distinctly more tender than those nearer the middle. This was found to be almost universally true, and in searching for the explanation it was thought that these differences were probably due to differences in age of the kernels as determined by the time of pollination of the silks. This idea was confirmed in conversation with Dr. C. P. Hartley, of the Office of Cereal Investigations, who has demonstrated that the silks from the middle portion of the ear are the first to appear and hence are first to become pollinated.

With the increase in maturity there was found to be a progressive increase in the resistance of the kernels to puncture. This will be shown by the series of curves of the different varieties of sweet corn tested which are presented herewith. As is to be expected of curves based upon the findings from but relatively few ears, irregularities in form are observed. These of course would be absent in curves based upon a larger number of tests.

Little comment upon these curves is necessary. Their outstanding feature is the pronounced and rather rapid rise indicating increasing toughness of the kernels. In no case did corn remain tender for any considerable period, though a tendency in this direction is shown in the case of Golden Bantam. Some varieties are distinctly tougher than others even while immature, as is shown, for instance, in the case of Crosby. (See fig. 4.) This slightly greater toughness of the Crosby, in some strains at least, was also observed in field studies in Maine during the 1922 canning season in which ears of about the same degree of maturity, as indicated by the thumb-nail test for the condition of starch, gave a little higher reading than was considered normal for most varieties at that stage grown at Arlington farm. Extreme toughness was attained by Country Gentleman (see fig. 6) and Kelly's Hybrid (see fig. 5) during the later stages, while several others, as, for instance, Golden Bantam, Dreer's Golden Giant, and Charlevoix (see fig. 4), did not approach an extremely high mark even at the end of 30 days. While these findings can not be analyzed in too great detail, being based upon the results of one season's work only and in a restricted area, they do show significant tendencies which deserve more careful study. It may be of interest to note the relation of toughness as indicated by these tests to corns in prime condition for canning. Conclusions drawn from these laboratory tests were surprisingly closely confirmed by a number of trained canning factory superintendents who were asked, during visits to various plants in Maine, to select ears from cannery stock representing corn in prime canning condition, ears that were immature, and those that were over mature. These combined to place the critical period, when corn was in prime condition, at the stage in which readings from 250 to 300 grams were obtained by use of the puncturing instrument. The reading of 325 grams was found very close to the "danger line" except in the case of some strains of Crosby mentioned above, which often were found to be still in the milk stage when this reading was obtained. Tentative conclusions based upon laboratory tests at Arlington experiment farm, Virginia, had already placed the readings of 250 and 325 as limits to the period during which the different varieties were in best canning condition.

It has not been possible in the present work to study fully the relation of temperature and other climatic factors to the increase in toughness of corn during

growth. Observations made in Virginia and Maine, however, indicate that in general no significant differences exist in toughness of corns which have reached canning maturity under the two sets of climatic and seasonal conditions. Apparent differences due to inherent characteristics of strains which have been touched upon above are considered as apart from this particular phase of the subject.

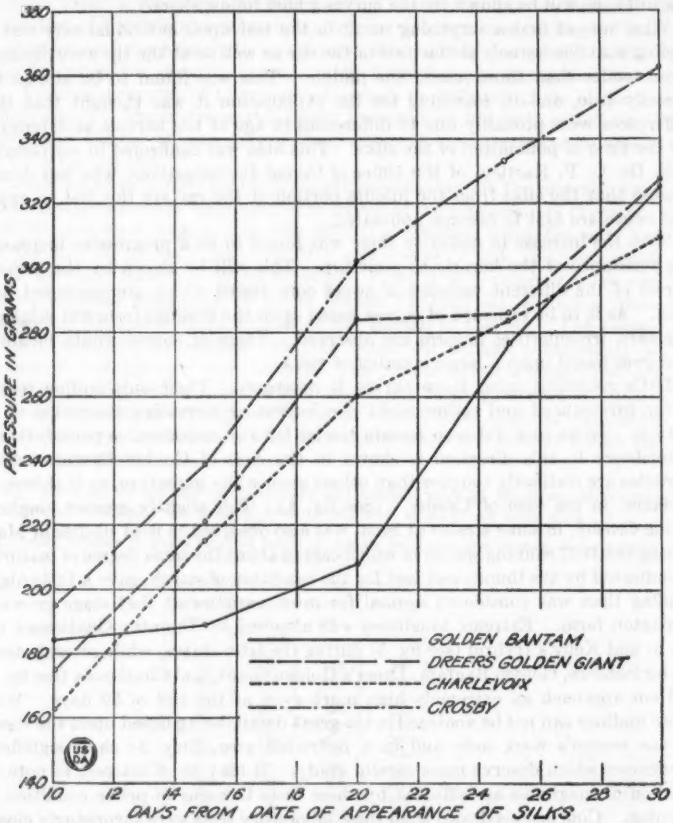

FIG. 4.—Curves illustrating the increase in toughness of kernels of Golden Bantam, Dreer's Golden Giant, Charlevoix, and Crosby sweet corns with increase of maturity

CHEMICAL STUDIES

During the growth and development of the ear of corn the products of metabolism are transferred to the kernel where they are utilized in part in tissue building and in part are laid down as storage materials. The transformations undergone in these processes and the nature and amount of these changes account for the differences in quality of corns at various stages of maturity. As concerned in these activities a number of organic substances may be mentioned such as crude fiber and other carbohydrates, fats and allied substances, proteins, and those substances which give characteristic flavor, the chemical nature of which is not known.

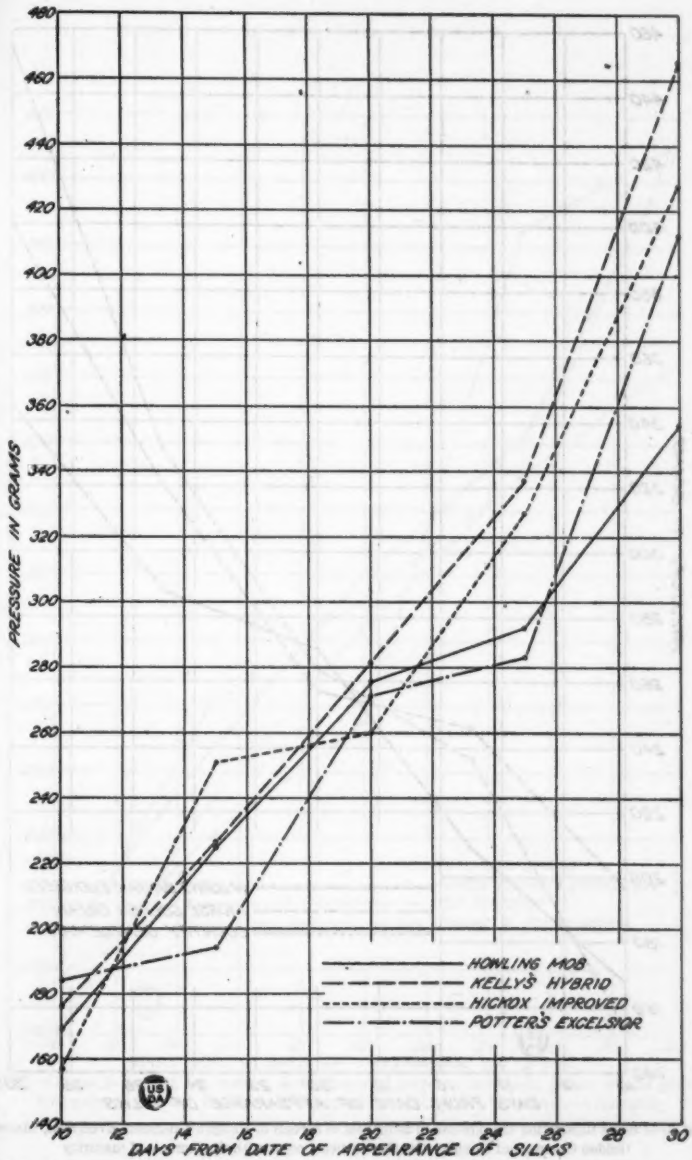

FIG. 5.—Curves illustrating the increase in toughness of kernels of Howling Mob, Kelly's Hybrid, Hickox's Improved, and Potter's Excelsior sweet corns with the increase of maturity

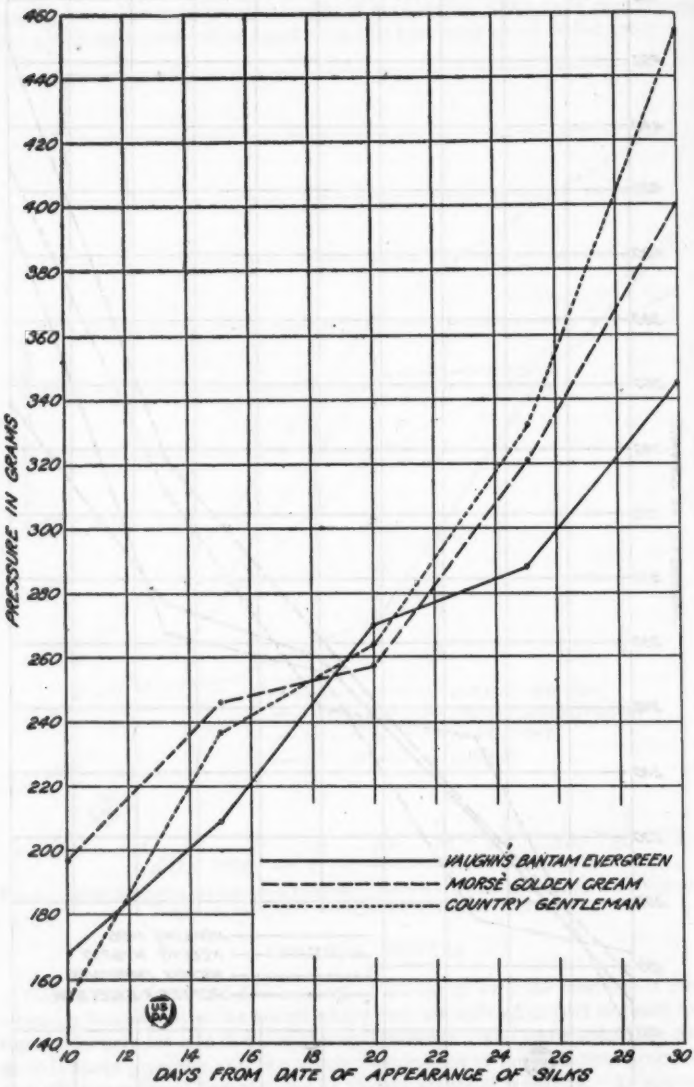

FIG. 6.—Curves illustrating the increase in toughness of kernels of Vaughn's Bantam Evergreen, Morses' Golden Cream, and Country Gentleman sweet corns with the increase of maturity

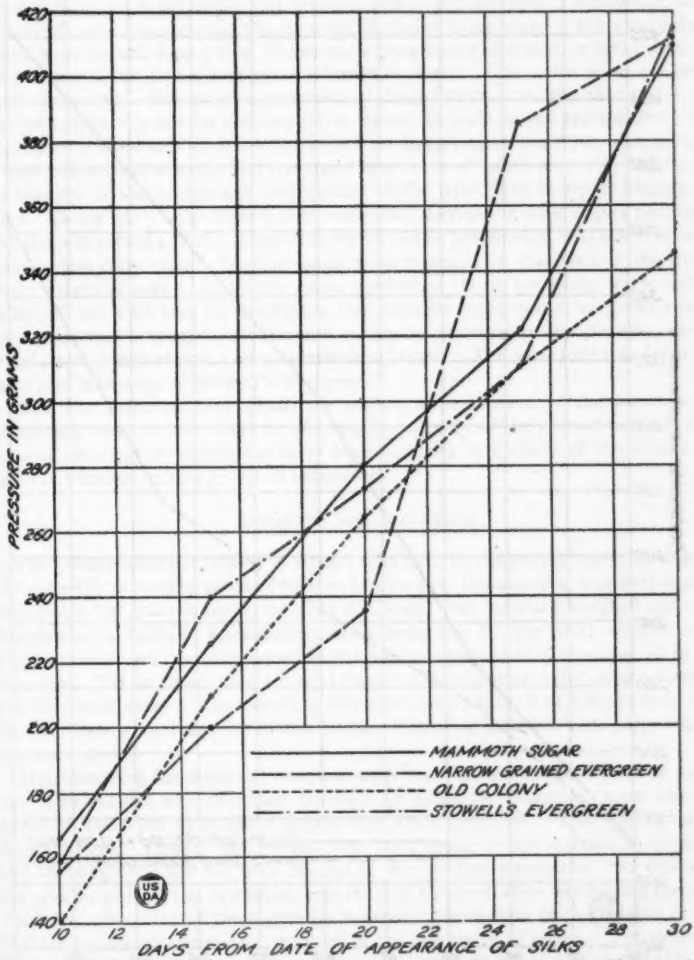

FIG. 7.—Curves illustrating the increase in toughness of kernels of Mammoth Sugar, Narrow-grained Evergreen, Old Colony, and Stowell's Evergreen sweet corns with the increase in maturity

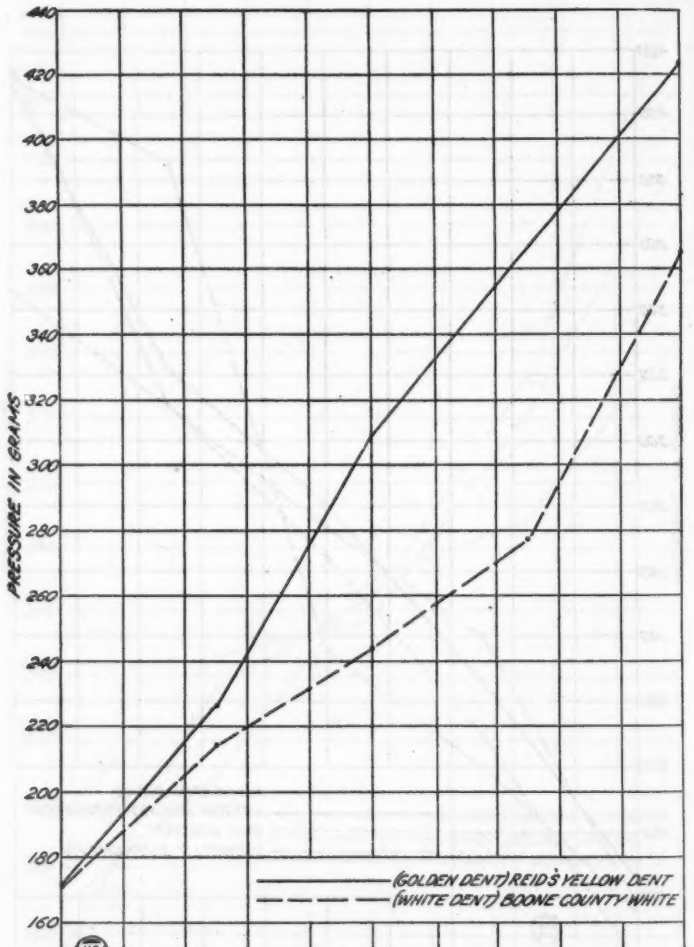

FIG. 8.—Curves illustrating the increase in toughness of kernels of Reid's Yellow Dent and Boone County White field corns with the increase of maturity

Much work has been done upon the chemistry of the developing maize plant, and the composition of the mature grains of sweet corn has been studied by a considerable number of workers. A much smaller number have given attention to the chemical transformations taking place during the growth and development of the kernels. The work of Salisbury (*54*), Atwater (*5*), Richardson (*50, 51*) and others has shown that the mature kernels of sweet corn have approximately the following chemical composition: Carbohydrates, 65 to 75 per cent; fats, 6 to 9 per cent; and proteins, 10 to 12 per cent. Appleman and Eaton (*3*), who have studied the chemical changes taking place in the developing sweet corn kernel, found that there was a progressive decrease in total sugars, an increase in fat, and a very great increase in starch. The crude fiber and proteins decreased. The exact significance of their figures from the standpoint of the fresh corn can not be determined, however, as their figures represented percentages on the basis of dry weight, and no figures upon moisture were given. These authors likewise studied early and late crops of sweet corn with reference to changes in the percentage composition of the fresh corn in equal lengths of time. In the early crop there was a progressive decrease in total sugars throughout the test period and the increase in starch, while progressive, was much slower than in the early crop. These findings were reported on the basis of the fresh green weight of corn. In a later paper Appleman (*1*), in his study of the reliability of the nail test for predicting the chemical composition of green sweet corn, recorded a progressive decrease in sugars throughout the premilk, early dough, and dough stages, and an increase in starch. The same held true for both early and late crops of Stowell's Evergreen.[5]

Since the carbohydrates constitute such a large portion of the sweet corn kernel and seem so important as affecting the quality of the canned product the present chemical investigations have been confined to a study of the nature of and the changes in this group of substances.

METHODS OF ANALYSIS

The kernels were cut from 5 to 20 ears (the number depending upon the degree of maturity) of freshly plucked corn of known age, the material was thoroughly mixed and 100 gram samples, taken in duplicate, were carefully weighed out and transferred to flasks.[6] Immediately after weighing, 95 per cent alcohol was added in sufficient quantity to make the alcohol content of the sample 70 to 80 per cent. The samples were brought nearly to the boiling point of the alcohol and then sent away. The sampling was concluded within 3 to 4 hours from the time the ears were taken from the stalks. Canning samples were prepared at the same time.

After standing for some days each sample was handled in the following manner: The alcohol was decanted through an extraction thimble, more alcohol added to the corn, thoroughly shaken and again decanted. This was repeated several times. Finally the residue was transferred to the extraction thimble and thoroughly extracted with alcohol in the Soxhlet apparatus. In this way the greater part of the extraction was done in the cold, thus minimizing the possibility of alteration of the sugars by heating. Extraction of the residue in the Soxhlet apparatus assured the removal of the last traces of sugar. The different portions of extract from a given sample were united and then brought to volume.

Aliquot portions of this extract were examined for sugars, determinations being made both before and after inversion with hydrochloric acid, according to the methods of the Association of Official Agricultural Chemists (*4*). The

[5] Percentages calculated on basis of dry weight.

[6] In the 5 and 10-day samples it was impossible to prevent the inclusion of a small amount of chaffy material from the cob. There was very little, however, in the other samples.

residue was used for the determination of polysaccharides. Total polysaccharides were determined by inversion with hydrochloric acid, estimation of sugars and calculation as starch. To determine the polysaccharides soluble in cold water 1 gram of the alcohol-insoluble residue was ground in a mortar with 40 to 60 c. c. of distilled water, allowed to stand for several minutes, the milky supernatant portion decanted, and the process repeated several times. Finally the whole was washed into a 250 c. c. volumetric flask and brought to volume with distilled water. The sample thus prepared was allowed to stand over night. The milky supernatant portion was then decanted, mixed with a small amount of dry infusorial earth and then filtered by means of suction through a dry asbestos mat filter into a dry flask. Aliquot portions of this were transferred to boiling flasks, inverted with hydrochloric acid and the sugars determined in the usual way. The cold-water-soluble polysaccharides were calculated as dextrin. Table III shows the results of the analytical work.

TABLE III.—*Showing results of chemical analyses of 17 varieties of corn sampled at intervals of 5 days throughout the whole growth period*

Variety and age in days from time of silking	Moisture	Dry matter	Total sugar calculated as invert	Reducing sugar calculated as invert	Nonreducing sugar calculated as invert	Water soluble polysaccharides calculated as dextrin	Total polysaccharides calculated as starch
Golden Bantam:							
5	89.45	10.55	4.01	3.36	0.65	0.30	1.43
10	88.62	11.38	4.75	3.11	1.64	.28	1.79
15	79.14	20.86	5.89	1.92	3.97	3.21	8.44
20	69.67	30.33	4.30	.89	3.41	8.90	17.46
25	62.98	37.02	2.82	.52	2.30	12.13	23.02
30	58.37	41.63	2.14	.67	1.47	13.97	27.73
Howling Mob:							
5	89.40	10.60	4.12	3.43	.69	.22	1.21
10	88.05	11.95	4.80	3.35	1.45	.18	1.80
15	82.29	17.71	5.67	1.90	3.77	2.50	6.47
20	71.50	28.50	4.55	.93	3.62	8.96	16.42
25	64.80	35.20	3.56	.67	2.89	11.81	21.25
30	62.95	37.05	2.06	.61	1.45	12.67	23.88
Dreer's Golden Giant:							
5	90.23	9.77	3.91	3.11	.80	.21	1.36
10	87.73	12.27	4.50	3.00	1.50	.16	1.78
15	79.93	20.07	4.81	1.57	3.24	2.54	8.63
20	70.04	29.96	3.88	.84	3.04	8.56	17.43
25	65.77	34.23	3.12	.61	2.51	10.56	20.47
30	61.73	38.27	2.00	.63	1.37	13.21	26.84
Charlevoix:							
5	90.62	9.38	4.05	3.34	.71	.20	1.32
10	88.02	11.98	4.61	3.25	1.36	.15	1.64
15	82.80	17.20	5.71	1.96	3.75	1.75	5.74
20	75.20	24.80	4.16	.76	3.40	7.09	13.41
25	69.03	30.97	3.24	.69	2.55	10.31	18.51
30	65.84	34.16	2.65	.58	2.07	11.23	21.51
Crosby:							
5	90.13	9.87	4.12	3.48	.64	.11	1.30
10	88.91	11.09	4.98	3.35	1.63	.14	1.73
15	80.61	19.39	6.05	1.93	4.12	2.75	7.30
20	70.00	30.00	4.25	.95	3.30	8.86	17.26
25	65.20	34.80	3.20	.70	2.50	11.14	20.88
30	59.29	40.71	2.20	.53	1.67	14.58	32.48
Morse's Golden Cream:							
5	90.19	9.81	3.73	3.15	.58	.16	1.41
10	87.79	12.21	4.73	2.57	2.16	.17	1.83
15	79.75	20.25	5.43	1.79	3.64	3.26	8.44
20	71.99	28.01	4.01	1.04	2.97	8.44	15.67
25	64.45	35.55	3.29	.72	2.57	11.48	21.50
30	58.52	41.48	2.68	.64	2.04	14.76	29.06
Kelly's Hybrid:							
5	90.00	10.00	4.08	3.48	.60	.21	1.39
10	88.09	11.91	4.85	2.90	1.95	.17	1.92
15	79.73	20.27	5.65	1.38	4.27	3.61	7.77
20	70.65	39.35	4.60	.90	3.70	9.05	16.65
25	67.46	32.54	3.45	.71	2.74	10.51	19.28
30	62.57	37.43	2.80	.52	2.28	13.19	25.55

TABLE III.—*Showing results of chemical analyses of 17 varieties of corn sampled at intervals of 5 days throughout the whole growth period*—Continued.

Variety and age in days from time of silking	Moisture	Dry matter	Total sugar calculated as invert	Reducing sugar calculated as invert	Nonreducing sugar calculated as invert	Water soluble polysaccharides calculated as dextrin	Total polysaccharides calculated as starch
Hickox's Improved:							
5	89.84	10.16	4.15	3.48	0.67	0.53	1.39
10	88.39	11.61	4.85	2.88	1.97	.10	1.70
15	78.52	21.48	5.73	1.60	4.13	3.25	8.68
20	69.37	30.63	3.90	.90	3.00	8.48	16.86
25	65.84	34.16	3.00	.64	2.36	11.30	22.34
30	62.28	37.72	2.85	.70	2.15	12.80	26.01
Potter's Excelsior:							
5	89.42	10.58	4.00	3.42	.58	.31	1.47
10	89.05	10.95	4.64	2.90	1.74	.15	1.70
15	80.69	19.31	5.23	1.47	3.76	3.23	7.48
20	73.13	26.87	4.60	1.07	3.53	7.83	14.78
25	66.23	33.77	3.06	.52	2.54	10.13	21.73
30	60.99	39.01	2.82	.63	2.19	13.63	26.23
Vaughn's Bantam Evergreen:							
5	90.17	9.83	4.13	3.36	.77	.19	1.35
10	88.43	11.57	4.72	2.17	2.55	.21	1.82
15	82.62	17.38	5.24	1.27	3.97	2.40	6.65
20	74.16	25.84	3.95	.92	3.03	7.08	14.34
25	68.02	31.98	2.59	.76	1.83	8.42	17.71
30	66.13	33.87	2.22	.62	1.60	10.31	21.46
Mammoth Sugar:							
5	89.32	10.68	4.26	3.52	.74	.15	1.45
10	88.88	11.12	4.78	2.80	1.98	.11	1.91
15	81.88	18.12	5.98	1.65	4.33	2.67	6.29
20	74.75	25.25	4.24	1.12	3.12	6.91	13.16
25	69.86	30.14	3.30	.79	2.51	9.53	17.62
30	64.56	35.44	3.04	.67	2.37	11.01	22.49
Old Colony:							
5	90.36	9.64	4.00	3.36	.64	.28	1.35
10	88.65	11.35	4.23	2.30	1.93	.16	1.64
15	83.10	16.90	5.12	1.58	3.54	3.07	6.65
20	74.17	25.83	4.24	.96	3.28	7.66	14.10
25	71.15	28.85	3.14	.73	2.41	8.55	16.85
30	66.52	33.48	2.80	.68	2.12	11.11	21.30
Narrow Grained Evergreen:							
5	90.76	9.24	4.01	3.30	.71	.13	1.26
10	89.05	10.95	4.58	2.64	1.94	.10	1.59
15	83.47	16.53	5.23	2.08	3.15	2.80	6.27
20	76.12	23.88	3.97	.97	3.00	6.69	12.92
25	72.61	27.39	3.54	.78	2.76	9.27	16.08
30	68.72	31.28	2.46	.63	1.83	11.14	19.80
Jountry Gentleman:							
5	90.53	9.47	3.81	3.07	.74	.10	1.38
10	88.30	11.70	4.37	2.73	1.64	.09	1.82
15	78.60	21.40	5.31	1.49	3.82	3.99	9.12
20	71.14	28.86	3.95	1.06	2.89	8.66	16.82
25	66.69	33.31	3.02	.75	2.27	11.62	21.76
30	61.34	38.66	2.68	.61	2.07	12.86	24.97
Stowell's Evergreen:							
5	91.01	8.99	3.82	3.14	.68	.10	1.24
10	89.26	10.74	4.60	2.64	1.96	.12	1.65
15	82.24	17.76	5.68	1.38	4.30	3.04	6.77
20	75.97	24.03	4.09	.96	3.13	7.56	12.90
25	72.07	27.93	3.38	.72	2.66	9.19	16.48
30	66.82	33.18	2.23	.70	1.53	12.66	21.95
Reid's Yellow Dent:							
5	90.17	9.83	3.62	3.00	.62	.06	1.55
10	89.73	10.27	3.95	2.84	1.11	.31	1.67
15	86.75	13.25	4.47	2.06	2.41	.25	4.85
20	75.75	24.25	2.90	1.10	1.80	.68	13.64
25	67.95	32.05	2.33	.64	1.69	.81	21.49
30	62.44	37.56	2.07	.43	1.64	1.04	27.90
Boone County White:							
5	89.85	10.15	3.73	3.27	.46	.08	1.28
10	89.60	10.40	4.28	3.45	.83	.10	1.62
15	86.44	13.56	5.84	2.68	3.16	.12	3.74
20	80.83	19.17	4.02	1.41	2.61	.34	9.34
25	73.45	26.55	3.52	1.18	2.34	.57	16.07
30	65.63	34.37	2.79	.83	1.96	.72	22.54

DISCUSSION OF ANALYTICAL DATA

MOISTURE CONTENT

It will be seen from the tables that in all varieties the moisture content decreases throughout the growing and ripening period of the ear. In the early stages the moisture content is fairly uniform for all varieties, but later on considerable differences are observed. These differences seem to be more or less closely correlated with the rate of maturing of the varieties. Golden Bantam, Dreer's Golden Giant, and Crosby are among those maturing most rapidly, and their moisture content is low during the later stages. Stowell's Evergreen, Mammoth Sugar and Old Colony are among the slow-maturing varieties and their moisture content during the later stages is seen to be somewhat higher.

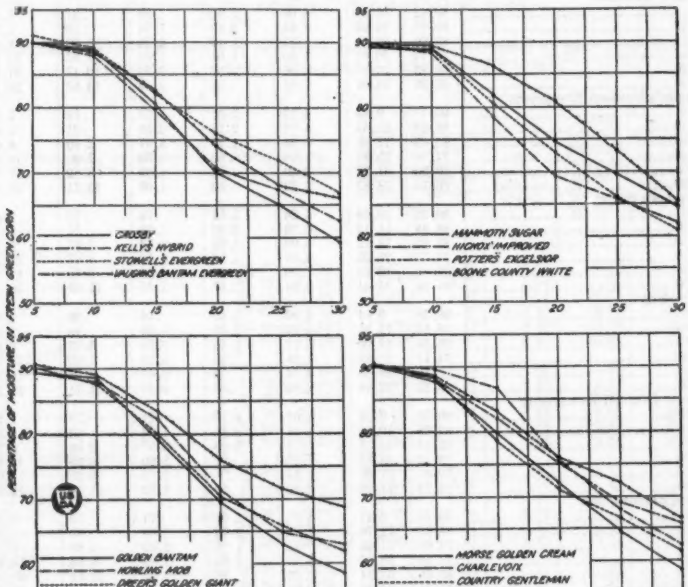

FIG. 9.—Curves showing the variations and changes in moisture content of the kernels of 15 varieties of sweet corn and 2 varieties of field corn during the development of the ears

Other varieties which are intermediate in rate of maturing are also more or less intermediate with respect to their moisture content. The two dent corns were even slower in development than Stowell's Evergreen and had correspondingly high percentages of moisture. It should be stated here, however, that the differences in the rate of development of the ear among the sweet corn varieties were much less than anticipated, and even at the 20-day stage are seen to be comparatively small. The principal difference between early and late-maturing corns lies in the length of time the plants require to come into flower rather than in the rate of development of their respective ears. Variations in the moisture content of the different varieties of corn at the various stages of their development are shown in the curves of figure 9.

SUGAR CONTENT

The total sugar is found to increase up to the 15-day stage and then to decrease rapidly at first and then more slowly during the later-maturing stages. The proportion of the reducing to nonreducing sugars is constantly changing. The reducing sugars decrease throughout the growing and maturing periods of the kernels. The nonreducing or cane sugar is low at first, increases rapidly to 15 days and slowly decreases. An idea of the rate and nature of these changes may be obtained at a glance from figures 10 and 11.

The different varieties of sweet corn do not vary widely at any stage of maturity in the quantities of sugar which they contain. At the ages of 5 and 10 days differences in amount are slight. The greatest variation seems to be at 15 days. With but a few exceptions the differences in sugar content at 20 days can not be considered as very significant. Kelly's Hybrid, Potter's Excelsior, and Howling Mob had the highest sugar content at this stage and Dreer's Golden Giant, Hickox's Improved, and Country Gentleman the lowest. In the slow-maturing varieties the sugar content decreased almost as fast as in the more rapidly maturing corns. This was contrary to expectation, and if found to be true from year to year, must be taken into account in choosing the proper stage for canning. Of the field varieties Reid's Yellow Dent is seen to be significantly lower in total sugars than the sweet varieties, but the differences between these and the Boone County White is not very marked. There is, however, at 20 and 25 days a lower percentage of nonreducing or cane sugar in both of the field varieties.

The relation of these analytical results to the findings in the quality of the canned samples will be discussed later in the consideration of that subject.

POLYSACCHARIDES

The nature and quantity of the polysaccharides in sweet corn, together with the moisture content, determine to a large extent the consistency of the canned product. They are, therefore, of considerable interest and importance in canning. In food value the three most important groups of the polysaccharides are the starches, dextrins and pentosans. The last-mentioned group is reported to be present in but small amounts in the maize kernel (*5*, *60*, *63*, *69*) and from the standpoint of canned corn do not seem to be significant. The present study has been confined, therefore, to the starches and dextrins.

From the analytical tables it is noted that in all varieties the content of total polysaccharides increases with age of the corn, but the rate of increase varies somewhat with different varieties. The slow-maturing corns, such as Stowell's Evergreen, Narrow Grained Evergreen, Mammoth Sugar, and Old Colony show a less rapid increase in the total polysaccharides than is observed in Golden Bantam, Dreer's Golden Giant, Crosby and others of the more rapidly maturing sorts. This is closely correlated with the differences in moisture content and, as will be shown in connection with the discussion of the canned material, with the consistency of the canned product.

Of the two field varieties the total polysaccharides in the Boone County White is somewhat below the average of the sweet varieties and in Reid's Yellow Dent it is no greater than in many of the sweet varieties. Great differences are observed, however, in the consistency of the canned product from the sweet and the field varieties, and since the total polysaccharides show no marked differences in quantity the nature of the polysaccharides must be important. It would seem that the amount of the water soluble portion might throw some light upon this matter. In the sweet varieties at 20, 25, and 30 days of age the water soluble portion varies from less than one-half to a little more than one-half of the total

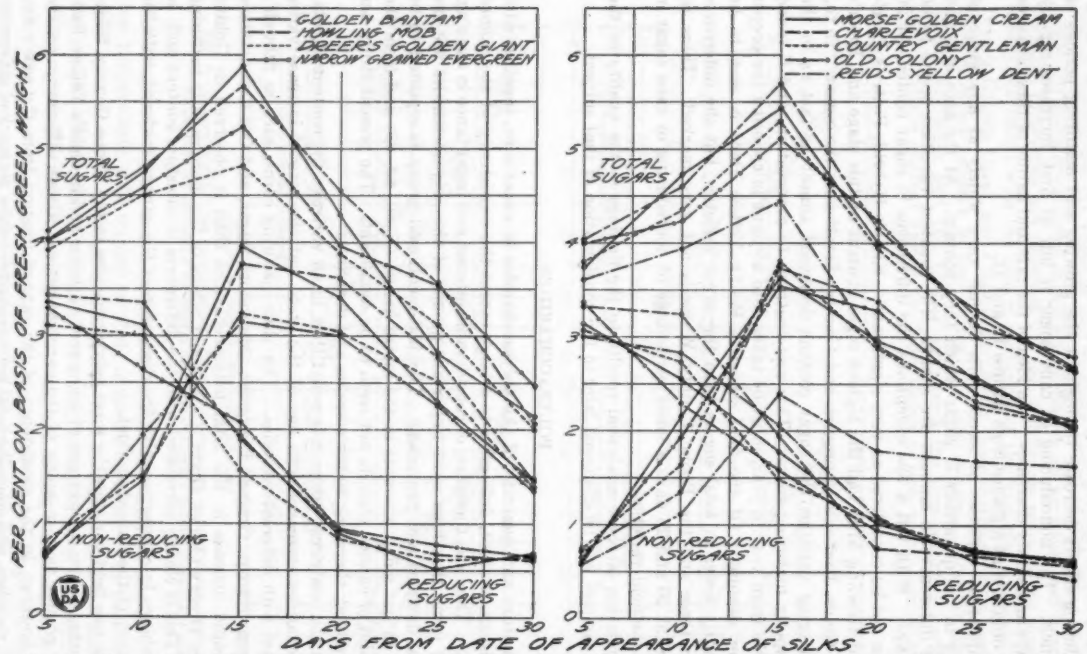

FIG. 10.—Curves showing the rate and nature of changes in sugar content of Golden Bantam, Howling Mob, Dreer's Golden Giant, Narrow Grained Evergreen, Morse's Golden Cream, Charlevoix, Country Gentleman, and Old Colony sweet corn and Reid's Yellow Dent field corn during the development of the ears.

Grained Evergreen, Morse's Golden Cream, Charlevoix, Country Gentleman, and Old Colony sweet corn and Reid's Yellow Dent field corn during the development of the ears.

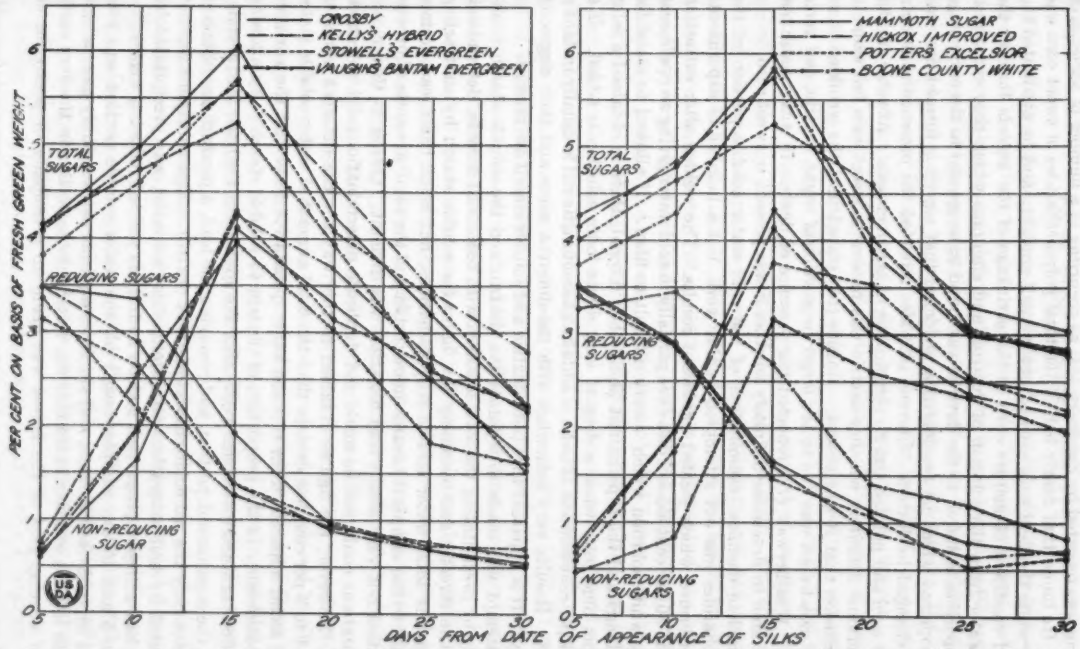

FIG. 11.—Curves showing the rate and nature of changes in sugar content of Crosby, Kelly's Hybrid, Stowell's Evergreen, Vaughn's Bantam Evergreen, Mammoth Sugar, Hickox's Improved, and Potter's Excelsior sweet corns and Boone County White field corn during the development of the ears

polysaccharides, while the amounts present in the field varieties are very small, usually less than 1 per cent. The water soluble portion seemed so important that it was thought worth while to learn something more about its chemical nature.

Dextrin was reported by Salisbury (*54*) as occurring in a number of varieties of maize. He found that nearly half of the total polysaccharides of sweet corn was dextrin, while the field corn showed but a small amount; and he attributed the wrinkled condition of mature corn to the shrinkage of the kernels through the loss of water from the solution of dextrins and albumins which they contained. The proportion of starch to the dextrin was found to be greater in the early stage of development which he considered as evidence that starch is formed first and is later changed to dextrin. Correns (*20*) also reported the presence of dextrin in sweet corn and pointed out its significance in maize crosses. Atwater (*5*) did not determine definitely whether dextrin was present in sweet corn but came to the conclusion that it was absent. Harper (*28*) stated that the wrinkled character of sweet corn was due to the larger proportion of sugar, dextrin, and gums present. Weatherwax (*71*) reported the presence of dextrin in waxy maize but was not able to determine definitely whether it was present in sweet corn.

A complete chemical examination of the cold water soluble portion of the polysaccharides was not attempted in this work, but a number of experiments were performed which yielded significant results. The residue after extraction with 70 to 80 per cent alcohol dissolves partially in cold water giving an opalescent or milky white solution which is very difficult to filter. If allowed to stand for several hours and the supernatant liquid then filtered, there is obtained a faint to distinct blue color when a drop of very dilute iodin solution is added. If a drop of 1 per cent solution of iodin is added a characteristic red is usually instantly obtained. Results vary somewhat with the different corns and their degree of maturity. It is apparent that both dextrin and soluble starch are present.

An attempt was made to separate the dextrin and the soluble starch quantitatively by precipitating the soluble starch with basic lead acetate, determining the dextrin directly and obtaining the figure for soluble starch by subtracting this from the total water soluble polysaccharides, but when basic lead acetate was added to the sample it became more turbid and the small amounts of precipitate settled out very slowly and filtration was difficult. Owing to this, clear-cut separations could not be made and duplicate determinations did not check closely. However, the figures obtained in this way for the different varieties showed 1 to 3 per cent less dextrin than the total amount of water soluble material. It seems apparent from this and other qualitative tests that the varieties differ considerably in the proportion of dextrin to soluble starch. By allowing the solutions to stand for several weeks after the addition of the basic lead acetate, filtering the supernatant portion, and removing the lead, a product was obtained which gave only the red color characteristic of dextrin. This substance was not precipitated by half saturation with ammonium sulphate, was precipitated by alcohol, had adhesive properties, and on hydrolysis yielded reducing sugars.

In the 5 and 10 day samples nearly all the water soluble portion was precipitated by basic lead acetate, and since the aqueous extract rarely gave a blue color with iodin it was concluded that the water soluble portion in the very early stages of development of the kernel was made up principally of pentosans or gums.

In the two field corns the water soluble portion gave a blue color with iodin, and was precipitated by basic lead acetate, and also by half saturation with ammonium sulphate thus indicating soluble starch; and in the later stage of maturity the water soluble polysaccharides in the field varieties appeared to consist entirely of starch.

Distinct and significant differences exist, therefore, between the polysaccharides of the sweet and the field varieties of corn, which differences are believed to be of very great importance from the standpoint of table quality.

TESTS UPON CANNING QUALITY

The sampling of the different varieties of corn for canning tests was begun upon ears at 15 days from the date when their silks first appeared and subsequent samples were taken at age intervals of 5 days, up to and including 30 days. The ears were plucked in the morning and taken at once to the laboratory where they were husked, silked, trimmed when necessary, and washed. The corn was cut from the cob "Maine style," that is, the outer one-third to one-half of the kernels cut off and the remaining edible portion scraped from the cob. In order that careful study might be made of the relation of the degree of maturity to the consistency of the canned product it was necessary that each can receive the same amounts of liquor and corn. Therefore, instead of mixing the cut corn and liquor in a precooker each was heated separately and measured quantities placed in each can. No. 2 "sanitary top" cans were used. The corn was precooked in steam heated vessels with frequent stirring until the temperature reached 85° to 90° C. (185° to 194° F.) and the liquor was heated in glass flasks to the same temperature; 120 cc. (4.2 ounces avoirdupois) of the hot liquor [7] was first placed in the can and 480 gm. (16.9 ounces avoirdupois) of the corn added, thus giving a 1:4 mixture. By putting the hot liquor into the can first a better mixture with the corn was secured than when the corn was introduced before the liquor. The cans were sealed immediately and processed as rapidly as the capacity of the equipment permitted. Those cans which could not be processed at once were held in a water bath at about 80° C. (176° F.) until they could be placed in the retort. The cook or process was for one hour at 121° C. (249.8° F.) in the steam retort, at the end of which time the cans were removed from the retort and submerged in cold water to cool.

At the end of the canning season and at irregular intervals thereafter series of cans representing all the varieties studied at their various stages of maturity were opened and subjected to critical comparative study by various groups of individuals qualified by experience and training to judge of the quality of the canned product. The results of these tests were as follows:

At 15 days maturity all varieties of sweet corn yielded a tender and sweet product but it was lacking in body and flavor and was classed as slightly too immature to grade as first-quality canned corn. Golden Bantam, Dreer's Golden Giant, and Morse's Golden Cream of the yellow and Crosby and Hickox's Improved of the white varieties were not far, however, from being in prime canning condition at 15 days.

At the 20-day stage all the varieties were judged to be in about prime canning condition, both from the standpoint of body or consistency and of flavor. Slight differences in sweetness were observed among the varieties and the consistency of the product varied somewhat, but aside from the differences in size of the kernels among some of the corns which made it possible to identify them readily, variations in flavor, sweetness, and with few exceptions, consistency, were too small to be of practical significance.

Among the later maturing varieties such as Stowell's Evergreen, Narrow Grained Evergreen, Mammoth Sugar and Old Colony the consistency of the canned product was a little thinner than with the earlier sorts. The explanation for this is to be found in the greater moisture content of these varieties as shown by the figures in Table III. The flavor and sweetness of both the earlier and the later corns were remarkably uniform and were found to be largely independent of the consistency of the canned corn.

[7] The liquor was prepared by dissolving 2½ per cent of salt and 6½ per cent of sugar in distilled water.

At the 25-day stage all varieties were past the prime canning condition from the standpoint of flavor and sweetness, and, with the exception of some of the later maturing varieties already mentioned, from the standpoint of consistency also. The kernels were tougher and the corns had lost much of their desirable flavor.

Of particular interest is the matter of the consistency of the product from the slow maturing varieties. At 25 days the consistency of their product was about the same as that of the earlier maturing corns at the 20-day stage. It is a commonly accepted idea that Stowell's Evergreen and some other varieties more or less closely related to it remain in canning and table condition for a longer time than do some of the earlier sorts, and from the standpoint of consistency of the canned product this has been found to be true. It should be pointed out however, that the sweetness and flavor are not maintained to the same degree, for, as may be seen by the table on the chemical composition mentioned above, the sugar content falls almost as rapidly in these varieties as in the others, and at the same age of the ears. Therefore, corn which may appear to be still in good table condition may yield a canned product of poor quality.

At 30 days all the varieties were far past the canning stage and further comment upon them is unnecessary.

One other significant fact which deserves mention was brought out in these comparative canning tests. At the outset of these investigations it had been expected to find that the product of such varieties as Golden Bantam and Crosby would be sufficiently distinct in flavor and other qualities from the other varieties as to make them characteristic and distinct, but this was not found to be the case with the corns used in the present comparative study. Whether this would hold true for the same varieties grown in other sections of the country is not known, but it is believed, however, that the degree of maturity rather than the variety used will be found to determine the quality of the product irrespective of locality where grown.

The results of canning tests upon the two dent corns are of considerable interest. These corns were slower in coming to the full milk stage than the sweet varieties, but Reid's Yellow Dent was considerably earlier than Boone County White. From the standpoint of the appearance of the contents of the raw kernel Reid's Yellow Dent would have been considered in prime canning condition at between the 20- and the 25-day stages. Boone County White, however, was still in the milk stage at 30 days.

It will be seen by reference to Table III that Boone County White at the 20-day stage has as high a total sugar content as many of the sweet varieties and by reference to the puncture tests (fig. 8) that the kernels were not particularly tough at this stage. A reasonably acceptable product therefore might have been expected. The canned product from this variety at 20 days was found to be sweet and of good consistency, but the kernels were distinctly harder than was the case with the true sweet varieties. The flavor of the product was somewhat inferior to that of the sweet corns, but the canned corn was nevertheless edible. At the 25-day stage the corn was nearly solid in the can and the kernels were hard and tough. The flavor was not unlike that of hominy. At the 30-day stage the corn was very hard and horny in texture, and it was only with difficulty that a spoon could be introduced into the canned product of both the 25- and the 30-day stages. It is of particular interest to note that at even 30-day stages the raw corn was still in the milk stage and by the thumbnail test would have been considered in good condition for canning.

The product from Reid's Yellow Dent was inferior to that from the Boone County White at all stages, being less sweet, poorer in flavor, and unattractive

in appearance. This variety at 25 days was still in the milk stage, but the product from the corn was hard and unpalatable even at 20 days.

From these results it seems apparent that some factor or factors other than moisture content and toughness of the kernel in the raw state determine the consistency and texture of the product from these varieties of field corn. Whether this would hold true for all field varieties remains to be determined.

GENERAL DISCUSSION

For a proper evaluation of the foregoing data certain general considerations must be held in mind, and before final conclusions are drawn from the work what appears to be significant facts deserve more attention than they have thus far received in the present treatment of the subject.

ENVIRONMENTAL CONSIDERATIONS

At the outset it should be remembered that with the exception of the comparative canning tests of preceding seasons the bulk of the work upon which the present report is based was confined to one season only, and the findings are known to apply, therefore, to but one location and one set of environmental conditions. While it is believed that the main facts brought forward here would be found applicable to all parts of the country, it is fully realized that a similar line of experimentation conducted in some other section of the country, or even in the same place but with differing conditions, might and doubtless would yield somewhat different results from those obtained in the present case. For example, temperature is known to have a very great influence upon the development of the maize plant, and without doubt it also materially affects the rate at which the corn matures in the ear. For this reason it is probable that in a more northern latitude the rate of coming to canning maturity would be somewhat slower than was found in the present instance. The amount and distribution of rainfall is likewise known to exert a powerful influence upon the progress of corn development, a severe drought during the latter part of the growing season materially hastening the ripening processes.

In view of the very important relation between maturity of the corn and the quality of the canned product as brought forth in this report, it seems highly desirable that similar work be done in the various sweet-corn-producing sections of the country to the end that canners may more effectively control the quality of their product by the consistent handling of the raw corn at the proper stage of maturity. The bringing together of such information from various sections of the country would likewise be of great scientific value by throwing light upon the physiology of the developing corn plant.

Another fact of importance to remember in the present connection is that corn as a plant is not only very responsive to environmental conditions but also that in the hands of growers and breeders the characteristics of a particular variety may be very materially altered in a few seasons. Many different strains of certain varieties have arisen in this way which are sufficiently unlike in their behavior to make it impossible to judge of the qualities of all by the observation of one. It has very frequently been claimed that corns from the same strain produced in different parts of the country behave differently when grown side by side. Therefore, it is probable that other strains of the varieties studied in the present case, or even the same strains the seeds of which had been secured from different sources, would have yielded different comparative results from those obtained in the present instance, even though grown under identical conditions. This emphasizes again the need for more experimental work along these lines on the spot where the various strains have been adapted to local environments.

WHEN IS CORN AT THE BEST CANNING STAGE?

To determine at what stage of maturity corns were in best condition for canning studies were made along several lines. The condition of the corn as indicated by physical development received careful attention in order to discover at what stage the highest yields in cut corn would be obtained and at what stage it would seem most advantageous to harvest the crop; chemical analysis of the cut corn was made at all stages of development that it might be learned at what period the amount and the constitution of the carbohydrates would indicate highest quality; and finally sample packs of the different varieties at various stages were prepared so that a test of the comparative table qualities of the canned products might be made. The close correlation of the findings from these three lines of study is of considerable interest.

From the standpoint of safe practice it would seem that the most favorable time to harvest corn for canning purposes would be at or very shortly after the time when the rate of development of the kernels had reached its peak, as beyond this time the rate of increase falls off rapidly and the hazards of successful packing are increasingly great. Careful study of the figures giving the percentage of cut corn from the husked ears at the different stages (see Table I) obtained in these studies, shows that in the great majority of cases the peak of the rate of development occurred in this instance at between 15- and 20-day stages, in no case occurring beyond the 25-day stage. This result is in close agreement with those supplied by the chemical analyses.

It is common knowledge that high quality in canned sweet corn is closely associated with high natural sugar content, and that added sugar does not give the same pleasing result as the sweetness supplied by nature. It is apparent therefore, that corn should be canned while the sugar content is high, and if possible, at the time when it is present in greatest amount. The chemical analyses made of the different varieties of sweet corn at age intervals of 5 days, in the present studies, showed that the highest point in the development of sugar under the present conditions was reached at the 15-day stage. This was found true for all varieties regardless of the time of planting or the earliness or lateness of the corn. It seems, therefore, that from the standpoint of natural sweetness canning should not be delayed for any considerable period beyond the 15-day stage.

These two lines of evidence are supported by a third, namely, the canning tests which have just been discussed. These all combine to point to a rather definite, brief period represented by the 20-day stage, or a few days earlier for rapid-maturing strains, during which it is possible to attain the highest quality in the canning of corn. Beyond this point the increase in yields are small, the products are lacking in natural sweetness, the desirable flavor is impaired and the kernels become increasingly tough.

THE RELATION OF SUGAR CONTENT TO SWEETNESS

In the consideration of the relation of the sugar content as indicated by chemical analysis, and the sweetness as indicated by taste, it needs to be pointed out that the total sugar content of a particular substance is not an exact measure of its real sweetness. Two factors are operative here, namely, the kind of sugar present and its concentration. Since cane sugar has higher sweetening power than dextrose, or invert sugar, changes in the relative proportions of these affect the sweetness even when the figures for total sugars present are the same. Since, also, the moisture content is constantly changing in the corn the percentage of sugar as shown by the analyses is not a real measure of the concentration. The per cent of sugar at the 15-day stage was found to be considerably higher than at 20 days,

but the difference in sweetness was much less marked than the figures would indicate. In the Boone County White at the 15-day stage the percentage of sugar was found to be about equal to any of the sweet varieties at this stage, but it was distinctly less sweet to the taste, due, apparently, to its higher moisture content, and hence a greater dilution of the sugar and to its smaller proportion of cane sugar. Where moisture content and other constituents are about equal, differences in sweetness are more nearly proportional to the differences in the percentages of sugar. In such cases the higher the percentage of sugar the higher the quality of the product.

There are, probably, other factors which affect the relation of sweetness to the percentage of sugar as practically all the 30-day samples of canned corn appeared less sweet to the taste than would have been indicated by the sugar content.

THE THUMBNAIL TEST

Judging of the chemical composition of corn in the field by the appearance of the ear or by the application of the common thumbnail test leaves much to be desired. When the test is applied to a number of varieties of the early, medium and late sorts it is not dependable and may be entirely misleading. It may be and is applied with considerable accuracy in judging of the maturity of a single strain with which the person making the test is familiar, but so great have been found the differences in composition of different varieties giving comparable results with the thumbnail test that except for indicating what would be the consistency of the canned product from the sweet varieties it proved of but little value. For instance, Crosby corn at the 20-day stage by the thumbnail test would have been judged to be at about the same stage of maturity as Stowell's Evergreen at the 25-day stage, but the chemical analyses showed that they were far from having the same composition particularly with respect to sweetness.

When used upon field varieties the test was found still more unreliable as it did not prove a safe index even of what the consistency of the canned product would be. Boone County White field corn at the 30-day stage would have been judged by this test to be only slightly more mature than Crosby at 20 days, and yet the consistency and texture of the products from the two varieties at these stages were as unlike as could be imagined; the Crosby being excellent in body and texture and the Boone County White so solid and tough that it could be removed from the can with a spoon only with great difficulty.

Failure of workers to take these facts into consideration has made the proper interpretation of their results extremely difficult if not impossible. Canning maturity is more closely associated with the age of the ear than with the physical condition of the kernel contents. Therefore, it is particularly important in experimental work that the investigator know as closely as possible the exact age of his material.

IMPROVEMENT OF VARIETIES

One of the chief values of a study of this sort is the help it affords by indicating the line of procedure which should be followed in the improvement of varieties of corn used for canning purposes.

In view of the importance of the tenderness of the kernel to the quality of the canned product it is believed that no greater service could be rendered by sweet-corn breeders than by giving attention to the development of tender strains from the standard canning varieties.

From the figures upon percentage yields of cut corn it is of interest to note that for both the yellow and the white varieties the highest yields were produced in this instance by the close-grained or many-rowed corns having deep kernels and correspondingly small cobs. The closer the kernels are set in the ear the

greater the yield is likely to be, providing, of course, the grains are of good depth. Increase in the number of rows to the ear and great depth of grain, together with greater tenderness are things to be particularly sought in sweet corn selection and breeding.

From the standpoint of sweetness and flavor in the canned product the corns producing quickly maturing ears seem to have the advantage over the slowly maturing sorts, the corn coming to canning maturity more closely to the time when the sugar content is greatest. Breeding for this character would, therefore, seem desirable.

Owing to the resistance of some of the late corns to bacterial disease there seems to be a need, also, for the selection of strains which will maintain a higher sugar content at the 20 and 25 day stages, thus making possible the utilization of these corns at later stages when greater yields of first-quality corn might be obtained. In this connection it seems, also, that the development of strains having a higher water-soluble polysaccharide content would be worth striving for. The crossing of the sweet with the waxy varieties having a very high dextrin content would seem to offer possibilities in this line.

Attention has already been directed to the rate at which different varieties of sweet corn under study came into flower, and it was noted that while silking in all the varieties continued for two weeks or more, in some the bulk of the silking occurred within a very few days, as, for instance, Golden Bantam and Country Gentleman. Although, as already mentioned, environmental factors, quality of the seed, etc., may have had some influence upon this particular result, it has seemed that a varietal characteristic was exhibited here which is worthy the attention of the corn breeder.

For home and market garden purposes an irregular or prolonged flowering period may be of advantage, as it increases correspondingly the number of days when corn may be picked in prime condition for table use. The reverse is true for corn grown for factory purposes. Several pickings from the same field is hardly feasible for the average farmer, and therefore the corn ordinarily delivered at the factory contains a considerable percentage of immature and overmature ears, which affect to a greater or less extent the quality of the product derived from it. Therefore, from the standpoint of large yields, high quality of the canned corn, seasonal hazards, etc., it is desirable that all the plants flower at as nearly the same time as possible, and that the subsequent development of the ears be highly uniform. It is believed that this characteristic of prompt development of the ears may be readily attained by careful selection in the existing varieties.

PREMIUM CORN

In conclusion, one other matter calls for serious consideration. It must be realized that all attempts in the attainment of high quality in canned corn are dependent upon the degree of cooperation between the grower of the corn on the one hand, and the canner on the other. The farmer grows the corn for the financial return it brings and it is natural that he should desire to realize as much as possible from the crop. Most farmers know that where compensation is based purely upon the weight of cut-off corn it is to their advantage to delay the harvesting as long as possible. Such a condition of affairs is inimical to the production of a first-quality canned product. From the standpoint of the canner, corn in prime condition is worth more than either immature or overmature corn and he must secure it in this condition if his pack is to be of the highest quality. Therefore, it would seem only fair to both grower and canner that quality be made the basis of compensation, the highest price being paid for corn in that stage of maturity which will yield a canned product of the finest quality.

SUMMARY

1. (*a*) In the maize plant the flowering period appears to be the most significant time from which to reckon its rate of development and maturity.

(*b*) In any variety, even when planted upon the same date, individual plants vary as much as two weeks or more in the length of time necessary for them to reach the flowering period. Thus, when a field of corn begins to come into flower the number of silks that appear each day increases for 6 or 7 days when a maximum is reached and then falls off until the end of the flowering period. Part of this appears to be due to environmental conditions and part to inherent variations.

(*c*) Up to 20 or 25 days of age the development of the individual ears silking at the same time appears to vary much less than the time of flowering, though small differences in this respect have been observed.

(*d*) The length of time between planting and flowering varies with the date of planting and depends upon temperature, rainfall, and other factors. Likewise, the rate of development of the ear is influenced to some extent by differences in seasons.

(*e*) There is often a wide difference among the varieties in the length of time between planting and flowering which largely accounts for their earliness or lateness. In the present studies among those varieties flowering early were Golden Bantam, Dreer's Golden Giant, Crosby, and Howling Mob, while Country Gentleman, Stowell's Evergreen, and Narrow Grained Evergreen flowered late.

(*f*) There is a small but often a distinct difference in the rate of developing and maturing of the ear in varieties silking at the same time. In these experiments Stowell's Evergreen and Country Gentleman flowered at approximately the same time, but the rate of development of the ear was somewhat different, the Country Gentleman maturing more rapidly.

(*g*) In the study of sweet corn varieties and their development it has been found advantageous to take samples for analysis and for canning from selected ears of the same age as determined by the date of silking.

2. (*a*) Data have been obtained upon 15 varieties of sweet corn and two varieties of field corn with respect to the weight of the ears and the proportions of cut-off corn and cob to both the husked and the unhusked ears at intervals of 5, 10, 15, 20, 25, and 30 days from the date of silking. Since many factors may cause variations from year to year in results of this sort and a relatively small number of ears were used in the tests, too close analysis of the figures must not be made. Great care was exercised in selecting the ears so that the figures would be as accurate as possible and it is believed that they indicate the general progress of changes in ears of corn under most conditions.

(*b*) The weight of the ear, and what is even more important the weight of the cut-off corn, continues to increase even 30 days after the date of silking. The most rapid increase was found to take place at between 15 and 20 days in the rapidly maturing corns and at between 20 and 25 days in the slow maturing varieties.

(*c*) Country Gentleman gave the highest proportion of cut-off corn and Golden Bantam the lowest in these tests. The small number of rows to the ears in this latter together with the greater proportion of husk probably accounts for this result. Other varieties giving high proportions of cut-off corn were, Stowell's Evergreen, Morse's Golden Cream, Narrow Grained Evergreen and Old Colony. Of the early varieties Crosby, Dreer's Golden Giant and Charlevoix gave fair yields. Few rows to the ear and shallow kernels result in low yields.

(*d*) No data were obtained upon the total yield per acre. The figures given in these records are based upon average ear yields which may or may not have any relation to total yields of varieties per acre.

3. (*a*) Information upon the comparative toughness of the kernels of different varieties of corn was obtained at 5-day age intervals throughout the growing and maturing period by means of an instrument devised specifically for the purpose. This measured the toughness of the kernels by showing the amount of their resistance to puncture. The features of this instrument are described and illustrated in the text.

(*b*) In general there is a relation between the resistance to puncture of the fresh corn and the toughness of the canned product made from it. Since the resistance to puncture increases with age, tests of this kind may be used to indicate in a general way the age of the corn which may facilitate the selection of the proper stage for canning.

(*c*) The variations in toughness among different corns of the same age were found to be relatively small, though in a few instances, as with Crosby, a distinct varietal difference in this character was observed.

(*d*) Factors other than toughness of the pericarp may affect the texture of the grain in the canned product as was shown in the case of the product from the two field varieties in which the kernels were found to be considerably harder than the puncture tests would lead one to expect.

4. (*a*) In all the varieties of sweet and field corn tested the moisture content of the kernels decreased continually during the growth and maturing periods. The rate of decrease varied considerably in different varieties, the rate being most rapid in Golden Bantam, Dreer's Golden Giant and Country Gentleman, and slowest in the Evergreens, Mammoth Sugar and Old Colony. Of the field varieties Boone County White showed a much slower decrease in moisture than Reid's Yellow Dent. The relative rates in the decreases in moisture in the different varieties was found to correlate closely with the relative rates in maturing as shown by field observations and the character of the product canned at various stages. The moisture content is also closely correlated with the consistency of the canned product of the sweet varieties, both as regards different varieties and different stages of maturity.

5. (*a*) The percentage of sugar in the kernels of green corn was found to change constantly during the development and ripening of the ear. The total sugar continued to increase up to 15 days from appearance of silks and then decreased rapidly throughout the maturing period. The reducing sugars were high at first and steadily decreased throughout the growth and maturing periods. In contrast to this the cane sugar increased rapidly at first to the 15-day stage and then slowly decreased as the corn approached maturity. The general order of these changes was practically the same for all varieties, the slowly maturing varieties decreasing in sugar content nearly as rapidly as those maturing more quickly.

(*b*) These changes in the percentage of sugars profoundly affect the sweetness of the canned product, though the percentage of total sugar is not an exact measure of the sweetness. This is determined rather by the nature and concentration of the sugar. That the composition of the sugar itself is changing is manifest by the change in the ratio of reducing to nonreducing sugar. Also the moisture content is constantly changing in the corn so that the percentage of sugar is changed without necessarily changing the concentration. These influences are manifested in the quality of the products canned at the 15 and 20 day stages. The percentage of total sugar in the corn at the 15-day stage is much higher than at the 20-day stage but the difference in the sweetness of the two products is not as great as the percentage of sugar would indicate.

6. (*a*) The total polysaccharides were found to increase continuously throughout the development and ripening of the ear of corn. As the nature and concentration of sugars were found to affect the sweetness of the canned product, in like manner the amount and nature of the different polysaccharides were found

to affect profoundly the consistency of the canned product. The sweet varieties contain a high percentage of water-soluble polysaccharides which appear to consist of dextrin-like substances mixed with varying amounts of material similar to soluble starch. In field corns these water-soluble polysaccharides were present in but small quantities and that principally in the form of soluble starch. When canned at comparable stages of maturity the kernels of the field corn were harder and tougher than any of the sweet varieties. This striking difference in cooking quality seems to be due partly to the difference in the nature of the polysaccharides.

7. (*a*) The so-called "thumb-nail test" proved to be unsatisfactory in the selection of corn for canning. It did indicate the rate of maturity and the moisture content, but it was not a safe guide in estimating the sugar content, especially when applied to different varieties.

(*b*) If the "thumb-nail test" were used to determine the best stage for canning, Golden Bantam and other rapidly maturing varieties would probably yield a better canned product than Stowell's Evergreen and others of the slowly maturing sort.

8. (*a*) Observations of three seasons lead to the conclusion that Stowell's Evergreen and allied strains do remain green and succulent for a longer time than Golden Bantam and some of the earlier corns. The "evergreen" property, however, may lead to the canning of an inferior product, as there is a tendency to delay the canning of these varieties longer than the early sorts. From the analytical results of one season it seems that the sugar content decreases almost as rapidly in the slow maturing as in the rapidly maturing varieties. This must be taken into account when considering the merits of the slow-maturing types.

9. (*a*) The different varieties of sweet and field corn were also subjected to comparative canning tests to determine their relative merits for canning purposes and to find at what stage of maturity they were in best canning condition. Canned samples were prepared at intervals of 15, 20, 25, and 30 days from the date of silking. and complete series of samples from these tests subjected to the critical examination of judges qualified by training and experience to pass upon their relative merits. Their findings are embodied in the conclusions here presented:

The 15-day samples were very sweet and tender, but were thin, watery, and lacking in flavor. However, the rapidly maturing varieties, such as Golden Bantam and Crosby, were only slightly too immature to be graded highest in quality.

The 20-day stage samples were still quite tender and sweet and of good flavor, but little variation was noted among the varieties in this respect. All exhibited a more desirable consistency than at 15 days, but Golden Bantam, Crosby, and others that mature rapidly gave a product of a little heavier consistency than did the slow-maturing types, such as Stowell's Evergreen.

At the 25-day stage the corns were tougher, less sweet, and the flavor less pleasing than at the 20-day stage. The rapidly maturing varieties yielded products of too heavy a consistency to grade as first quality, but the slowly maturing types were thinner and about the same as of the early maturing varieties at the 20-day stage.

At the 30-day stage all varieties were too mature for canning, the product in all cases being dry, tough, and very poor in flavor.

In spite of the above-mentioned differences in varieties they were very nearly the same in their general quality. Differences were found to be too slight to be significant, it being found practically impossible to identify varieties by quality alone. When canned at the same age, especially at 20 days, it was very difficult to decide which variety should be given first place, and judges differed widely in their choice.

(*b*) There was unanimous agreement that corns at the 20-day stage yielded a better canned product than at any other stage studied. There appeared to be a combination of a number of independent characteristics which made the products at this stage most desirable.

(*c*) The two varieties of field corn which were canned in the same manner as the sweet varieties were judged to be much inferior to the sweet sorts at comparable stages. In view of the greater moisture content, the hardness and toughness of the kernels, the poorer flavor, and the difference in the nature of the polysaccharides, there would seem to be little possibility of making a satisfactory canned product from these by any modification of the usual methods.

10. It appears that a first-quality canned product can be made from any sweet variety if the canning is done when the corn is at the proper stage of maturity.

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THE PHOTOPERIODISM OF TEPHROSIA CANDIDA[1]

By T. B. McClelland

Horticulturist, Porto Rico Agricultural Experiment Station

INTRODUCTION

Garner and Allard[2] through their observations and discussions on the effect of length of day on plant growth have opened a new and broad field for investigation.

Variation in the duration of exposure to daylight would seemingly have small influence on plant growth in the Tropics, where the range in day length is much more restricted than it is in the temperate regions. Such, however, is not the case, any change in day length being sufficient to exert a marked influence on plant growth. A knowledge of this influence as a factor in the growth of plants is of relatively greater importance in the Tropics, where plantings may be made every day in the year, than it is in the temperate regions where, at least in the higher latitudes, the planting season is more or less narrowly restricted by temperature.

The observations recorded in this paper were made at Mayaguez, P. R., which is little less than one-fourth degree north of the eighteenth parallel of north latitude. As is graphically shown in figure 1,[3] the time between sunrise and sunset in Mayaguez ranges from 11 hours in December to 13.2 hours in June.

PRELIMINARY OBSERVATIONS

Tephrosia candida, a tropical legume which is used as a cover crop, was selected for observation of the effect of variation in length of day on blossoming and growth. *T. candida* is a woody plant which attains a height of 9 to 11 feet. It makes a good stand for about 18 months, after which it gradually weakens and dies. In some instances, however, the plants outlive the second year.

Plantings were made in duplicate rows at intervals of 14 days between December 21, 1921, and December 20, 1922. The rows were uniformly 25 feet in length, and were numbered consecutively from 1 to 27 with the date of planting, each two rows that were planted on the same day bearing the same number. The plants were thinned to 50 to the row.

The inflorescence is terminal and at first looks like a tiny, green, erect tassel. As soon as the tassel appears, the plant is considered as having budded. An examination in the field of 100 plants, which were considerably older than those in the experimental rows, showed the presence of two budded plants on April 12, and again on May 9, 1922. Five plants were in blossom, or had developed young pods, and 10 were budded May 23; 6 bore young pods and 17 others were budded June 2. No further observations were made of these plants as budding was soon afterwards noticed in the experimental rows. Between June 13 and June 26, 108 plants were budded in the 8 rows of the four earliest plantings, which was over one-fourth of the total number of the plants in these rows. No buds were observed, however, in the younger rows. The budded plants were labeled and dated for observation. About a month later, it was observed that the

[1] Received for publication Mar. 6, 1924.

[2] Garner, W. W., and Allard, H. A.—Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Agr. Research 18: 553-606, illus. 1920.

[3] Data furnished by the U. S. Dept. Agr., Weather Bureau, San Juan, P. R.

plants were making little or no progress toward flowering, the small tassels in some instances atrophying accompanied by a change toward vegetative growth in the nearest leaf axils.

Only four plants blossomed prior to September 15, while more than a thousand opened their first flowers between September 15 and October 15, mainly in the last 10 days of September and the first 10 days of October. In rows No. 1 to 10, inclusive, which were planted between December 21, 1921, and April 26, 1922, 99 per cent of the plants were in blossom by the end of October. Eighty-eight per cent of the plants were in blossom in rows No. 11, 71 per cent in rows No. 12, and 19 per cent in rows No. 13. Rows No. 14, which were planted June 21, 1922, and all later plantings, failed to blossom (Pl. 1, A and B). The height of the plants in the various rows at this time is graphically shown in figure 2, the plants in rows No. 1 to 13, inclusive, ranging from less than 3 to more than 8 feet in height.

Toward the close of October, comparatively few blossoms opened, and the plants bore numerous pods. Only 1 or 2 per cent of the plants bore blossoms from early November until the middle of January, at which time 3 or 4 per cent

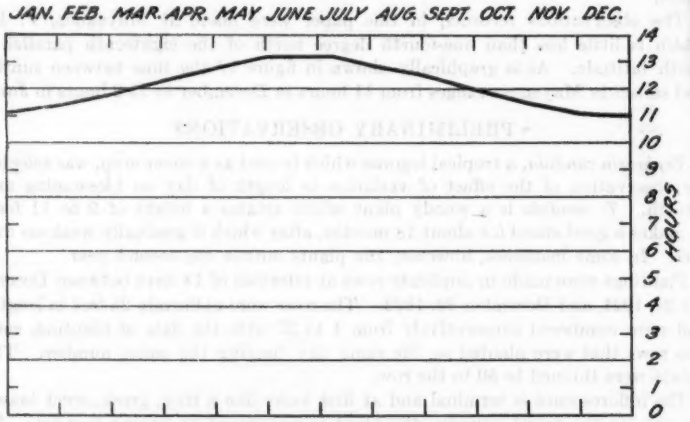


FIG. 1.—Length of day in hours, sunrise to sunset, Mayaguez, P. R.

flowered. Only three plants in the entire field blossomed in February. With the exception of one of these, all the plants blossoming in the winter had come into blossom in the autumn and continued to open a few scattered flowers now and then instead of setting heavy panicles of bloom. The only plant bearing flowers in March was one of the three which was seen with blossoms in February. The April record showed one, and the May record, two plants in blossom. Although only two plants were in flower June 20, 1923, many produced the tassel-like terminal tip of the young inflorescence. The tips later failed in most instances to produce flowers, and the plants resumed vegetative growth.

Plate 2, A, shows an atrophied inflorescence in the center of a representative specimen at the right, with vegetative growth well developed in the nearest leaf axils, and a number of shoots in varying stages (August 1, 1923). These shoots at first appeared as young inflorescence, but later instead of developing the terminal raceme or panicle of flowers, produced a stem of numerous short internodes wholly different from normal vegetative growth, followed or topped by normal growth of the stem and leaves (Pl. 2, B). By the end of August, about 6 per cent of the plants bore either flowers, or pods resulting from recent flowering, and about 54 per cent had budded.

It was noted that less than 2 per cent of the plants bore flowers on September 12, but that budding was very general. Approximately 5 per cent of the plants were in blossom by September 19, one-fourth of the total number were in blossom by September 26, and about one-half by October 3. Three-fourths of the total number were in flower or bore buds, which were about ready to open, by October 10. An examination of a half section of the field comprising 27 rows, one of the two rows planted on each planting date, showed that only about 8 per cent of the plants had failed to bloom by this time. Blossoming in the field was practically over by the end of the first week in November.

The blossoming record of the two seasons shows that, with a day length favorable to blossoming, practically all plants, except, of course, those weakened by age or disease, as old as 6 months (rows No. 10, planted April 26, 1922, the plants of which blossomed the following autumn), and a number only 4½ months old (rows No. 13, planted June 7, 1922), may be expected to bloom. The record also shows that plants that are much younger than 4½ months at the blossoming season will not only pass the first season without flowering, but will also not develop flowers until the return of the favorable day length the following year. This was exemplified by plants (rows No. 14 and higher) which, although planted June 21, 1922, and later, did not blossom until the autumn of 1923, when some were 15 and 16 months old. The results clearly show that the blossoming season of plants having reached a sufficient maturity is very definitely determined by the day length instead of by age.

The record further shows that (1) there is, in the course of a year, only one comparatively short and very definite season of heavy blossoming which reaches its height in midautumn; (2) this season is followed by a period covering several months during which a very few scattered flowers may open on plants that have already blossomed; (3) although there are indications of budding in the spring or early summer, such budding, except in some few instances, is not followed by flowers after a sufficient lapse of time; and (4) vegetative growth is resumed and in turn is followed by blossoming at the same season as in the preceding year.

EFFECT OF VARYING THE DAY LENGTH ON BLOSSOMING

In order to determine the effect on the plants of artificially protracting or shortening the length of daily exposure to light, a series of plantings was made in oil cans having a capacity of 5 gallons. The cans were uniformly filled with river-bottom loam. Three plants were grown to a can, two cans being planted with *Tephrosia candida* simultaneously with each field planting, and correspondingly numbered with the rows planted the same day. One of each pair of cans was lettered "A," and the other, "B." The plants in the A series were exposed to varying day lengths. Those in the B series were exposed to normal day length.

Since for the artificially shortened day the light exposure began abruptly, and for the artificially lengthened day terminated abruptly with the turning off of the electric light, a day artificially shortened or lengthened to 12 hours with only a single twilight exposure was shorter than the corresponding natural day of 12 hours between sunrise and sunset with its double twilight.

To give the plants additional light exposure, the cans were placed below a framework, 4 by 6 feet, carrying 6 tungsten filament incandescent lights, each rated at 25 candlepower, set 3 by 4 feet. An adjustable screen and black curtain, provided to furnish two distinct exposures, effectively protected half the space from the light used by the other half when two of the lights at one end were switched off. It being feared that the intensity of light was insufficient, the two middle lights were replaced by two of 60 candlepower at the end of the seventh week of lighting, and one at each end was replaced by one of 40 candlepower 9 days later.

The lights were switched on before sunset and off at the number of hours after sunrise requisite for making the desired light exposure or day length. All of the plants in the A series were given a 10-hour daily exposure at first. The day length was later modified in different ways until the autumnal equinox, 1923, from which time all the plants of the series were exposed to normal day length until the close of the period of observation, November 30, 1923. The following were the modifications made in the 10-hour daily period:

Plants in cans No. 1 to 18, inclusive, A series, were divided into groups 1, 2, and 3, November 10, 1922.

Group 1: Plants in cans No. 1, 4, 7, 10, 13, and 16 were subjected to a 10-hour day as before until March 14, 1923, when the day was lengthened to 12 hours.

Group 2: Plants in cans No. 2, 5, 8, 11, 14, and 17, were subjected to a 12½-hour day for 10 weeks, that is until January 19, 1923, and then to a 12-hour day.

Group 3: Plants in cans No. 3, 6, 9, 12, 15, and 18 were subjected to a 13½-hour day for 10 weeks, that is until January 19, 1923, and thereafter for 4 weeks to a 13-hour day, then for 2 weeks to a 12½-hour day, and finally, to a 12-hour day.

The plants in the remaining cans of the A series, No. 19 to 27, inclusive, were subjected to an 18-hour day length the first week after March 14, 1923, and the length was thereafter reduced by one-half hour weekly until May 17, after which it remained at 13½ hours for 2 weeks, and then was further reduced to 13.2 hours, the normal day length, for 1 week. After June 6, the cans of this lot were divided into groups 4 and 5.

Group 4: Plants in cans No. 20, 22, 24, and 26 were subjected to normal day length.

Group 5: Plants in cans No. 19, 21, 23, 25, and 27 were subjected to a 12-hour day length.

When subjected to the normal day length, the plants in cans flowered during both seasons a little later than did those in the field. Flowering and fruiting were normal, otherwise.

In cans No. 1 to 13, inclusive, B series, one or more plants came into blossom within a period of two weeks, October 11 to 25, 1922, and all but four which opened their first flowers in November had blossomed by the end of October. (Pl. 3, A.) Plants in cans No. 14 to 27, inclusive, B series, like those in the field tests, produced no flowers, all planted as late as June 21 failing to bloom.

The plants in cans No. 1 to 13, inclusive, A series, which had been given a 10-hour day throughout this period, showed no indication whatever of budding. (Pl. 3, B.)

By October, 1923, of the 39 plants in cans No. 1 to 13, inclusive, B series, 2 had died and 3 had made a very poor weak growth. Of the remaining 34 plants, 22 came into their second blossoming in October, and 6 in November.

The regularity in effect of the recurrent annual factor which induces blossoming may be noted by a comparison of the dates on which first blossoms appeared in cans No. 1 to 13, inclusive, B series, during two seasons, as shown in Table I.

Plants in cans No. 14 to 27, inclusive, B series, produced their first blossoms in October, 1923, when 31 of the 41 still living plants came into blossom. In November, 6 of the remaining 10 blossomed, 2 showed well-defined buds, 1 died budded, and 1 which had tasseled in October failed to develop.

That the interval between the first indication of budding, the appearance of the terminal tassel, and the opening of the flowers is closely related to the day length, was shown by observations made on the dates of the first budding and of the opening of the flowers. The plants in cans were carefully examined at weekly intervals for the first appearance of tassels. Table II gives the dates on which the tassels were first observed on 20 plants in cans No. 19 to 27, inclusive, B series, and the dates on which each opened its first flower.

TABLE I.—*Comparison of dates of two seasons during which plants in cans No. 1 to 13, B series, opened their first blossoms*

Can No.	October	
	1922	1923
1	17	16
2	21	24
3	18	18
4	17	19
5	25	24
6	23	25
7	14	16
8	15	(a)
9	22	31
10	14	16
11	11	18
12	19	24
13	16	15
Average dates of opening	18	20

a Date not noted, but was apparently within the preceding week, Oct. 16.

TABLE II.—*Showing interval between first observance of budding and opening of flowers on 20 plants in cans No. 19 to 27, inclusive, B series*

Date budded	Date flowered	Interval between budding and flowering	Average interval between budding and flowering
		Days	*Days*
Aug. 15	Oct. 9	55	
Do	Oct. 10	56	
Aug. 22	Oct. 9	48	
Do	Oct. 13	52	52
Aug. 29	Oct. 15	47	
Do	Oct. 16	48	
Do	Oct. 23	55	
Sept. 5	Oct. 16	41	
Do	Oct. 18	43	
Do	Oct. 27	52	46
Do	Oct. 28	53	
Sept. 12	Oct. 26	44	
Do	Oct. 27	45	
Sept. 26	Oct. 23	27	
Do	Oct. 26	30	
Do	Oct. 27	31	31
Do	Oct. 30	34	
Oct. 3	Oct. 22	19	
Oct. 10	Oct. 31	21	21
Do	Nov. 3	24	

The interval between the noting of budding and flowering averaged 52 days for plants budding in the last half of August, 46 days for those budding in the first half of September, 31 days for those budding in the last half of September, and only 21 days for those budding in the first half of October, when the day is 12 hours and less in length. As the days shortened, the interval proportionally shortened. Although there was a difference of 56 days between the earliest and latest dates on which the first buds were observed, all plants opened their first blossoms within a period of 25 days.

Groups 4 and 5, for which these cans were the controls, were subjected to a very long daily light exposure which was rapidly reduced. They did not differ in treatment until June 6, when the daily light exposure of group 5 was reduced to 12 hours. Group 4 was subjected to the normal day length, which remains at 13.2 hours from May 31 to July 11. As was true of the controls, group 4 showed

tassels in August and September, and opened first blossoms from September 23 to October 15. The August buds required on the average, 49 days to open, and the September buds, but 29 days. Group 5, however, with its artificially shortened 12-hour daily light exposure, showed tassels from June 27 to July 18, and opened first blossoms from July 20 to August 4, the interval between the first observance of tasseling and the date of blossoming averaging but 18 days.

If the autumn blossoming were merely the result in due time of the long summer days alone, group 4, which was subjected to an artificially lengthened day in spring merging into the long days of summer, would have been expected to blossom before the normal blossoming season. Four of the 12 plants in this group died before October, and the others opened their first blossoms between September 23 and October 15.

Group 5 was subjected to the same artificially lengthened day in spring, but the daily light exposure was shortened to 12 hours after June 6. The plants in two cans in this group failed to make vigorous growth, one dying of a root disease in August, and none blossoming. The remaining nine plants opened their first blossoms between July 20 and August 4, which was 7 to 9 weeks ahead of the earliest blossom in group 4.

The behavior of these two groups showed that blossoming was inhibited so long as exposure to the long days of summer continued, but that it was promptly induced by shortening the length of the daily exposure to 12 hours.

Plants in cans No. 1 to 18, inclusive, A series, were given a 10-hour day exposure at first, and all passed the autumn blossoming season, 1922, without flowering. The plants in 13 of the cans were of sufficient age to blossom, however, and their controls did blossom. Blossoming had been completely inhibited by a 10-hour day length.

In November, these 18 cans were divided into three groups, group 1 continuing with a 10-hour day, group 2 receiving a 12½-hour day, and group 3 a 13½-hour day for 10 weeks, at the end of which time budding was not evident. The artificially lengthened day was then shortened by one-half hour for each group. After four weeks, it was again shortened by half an hour for group 3. Two weeks later it was brought to a 12-hour length, where it was maintained for both groups.

A week after the first reduction in day length, budding appeared to be starting. A week later, budding was noted on 7 of the 14 plants in group 3 (1 in can No. 12, and 3 in can No. 15 having died), which had been subjected to the longer day, and on 1 of the 16 plants in group 2. With the exception of 2 weak, poor plants in can No. 3, which had been kept the longest of its group at a 10-hour day, and 1 plant which died budded in April (can No. 6), all the plants in group 3 opened their first blossoms between April 4 and April 27. (Pl. 4, A.)

Group 2, which had received only a 12½-hour light exposure as its longest day, showed a much less pronounced tendency to come into blossom than did group 3. The first plant opened its first flower March 31, and 3 plants came into blossom in May, and 1 in each of the months of June, July, and August. Of the remainder, 7 died between May and October, and none flowered.

The light exposure of group 1 was changed on March 14 from 10 to 12 hours. Two plants came into blossom in July, and 2 in August, but the others failed to blossom.

From the behavior of these plants under varying day lengths, it is concluded that a day length of 10 hours is too short, while one equaling that of a June day in this latitude, 13.2 hours, is too long, for flowering, and that an intermediate day length is necessary to induce blossoming. While blossoming may occur under a suitable day length, whether the preceding days have been too long

or too short, the impulse to blossom is much more pronounced when the preceding days have been long rather than short, long days followed by shorter days quickly bringing into expression the reproductive process.

The explanation of the phenomenon of spring budding not being followed by flowering is that the reproductive stage is initiated by the spring days of favorable length, but that its further development is inhibited by the longer days of summer which induce a return to vegetative development. The starting and then the arresting of the reproductive stage, followed by the resumption of vegetative growth, are especially interesting in the Tropics, where winter cold cannot be considered as a possible factor in the arrested development of the reproductive process.

The growth of the plants is decidedly affected by the day length.

In figure 2, the height of the plants in the various rows in the field is shown for three different dates. The growth made during the short days from November to March, inclusive, amounted to very little for the plants in the older rows, rows No. 1 to 12, inclusive, increasing less than a foot in height, while the growth of the plants in the younger rows was much less than that made in the following four

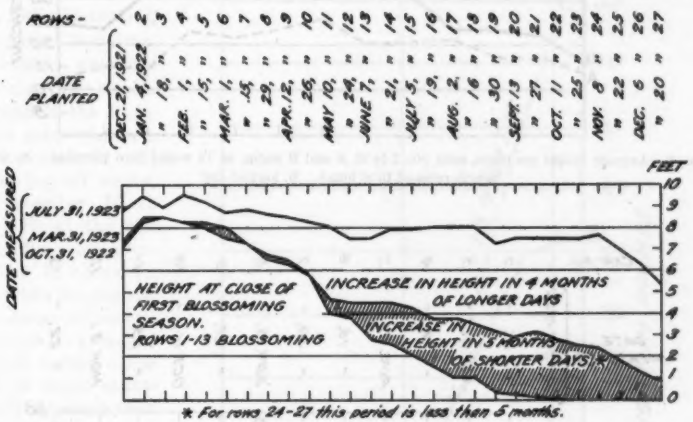


FIG. 2.—Growth in field

months with longer days. As the rainfall in this latter period is much more plentiful than it is in the earlier period, moisture, as well as day length, doubtless accounted for the increased growth. The cans were protected at this time from rainfall, but were well and frequently watered at all seasons. The height of the plants in cans No. 1 to 13, inclusive, B series, averaged 28.9 inches at 12 weeks from planting, while the correspondingly numbered plants, which were kept at a 10-hour daily exposure, averaged only 19.1 inches. The same plants at 24 weeks average 63.4 and 44.1 inches, respectively, in height.

Plants in cans No. 1 to 13, inclusive, B series, were measured at 12 weeks from planting. With the exception of one, all the plantings made between December 21 and April 12 and measured between March 15 and July 5, showed a steady increase in height (fig. 3). The day length began to shorten before the middle of July. Plants attaining the age of 12 weeks after July 15 showed a decrease in height, which was probably attributable to the inception of the reproductive stage. Measurements of height at 24 weeks showed the tallest growth on plantings of late March and early April, measured just prior to the blossoming season (fig. 4). The maximum difference in height between controls and treated lots was

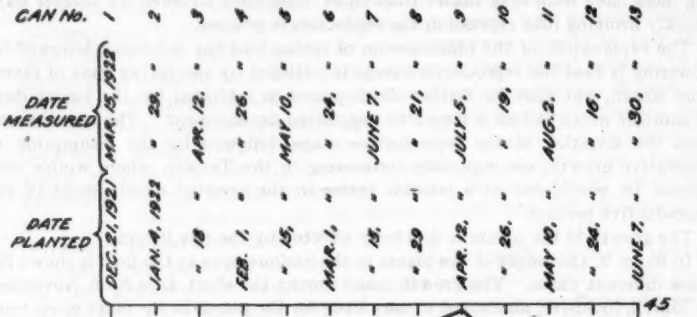


FIG. 3.—Average height per plant, cans No. 1 to 13, A and B series, at 12 weeks from planting. A, day length reduced to 10 hours. B, normal day

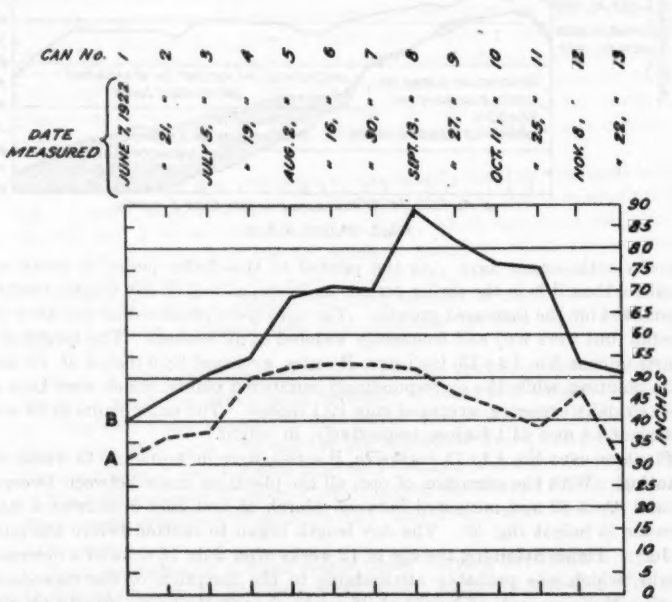


FIG. 4.—Average height per plant, cans No. 1 to 13, A and B series, at 24 weeks from planting. A, day length reduced to 10 hours. B, normal day

shown by plants in cans No. 8, which were planted March 29 and measured September 13, the B series measuring 82½, 89, and 93 inches in height, and the A series, 49½, 53½, and 54 inches. (Pl. 4, B.) These measurements showed individually and collectively that a reduction of day length to 10 hours had greatly retarded apogeotropic growth.

The opposite effect, achieved by lengthening the days, was shown by the plantings of August 16 in cans No. 18. Those of the A series were subjected to a 10-hour daily exposure for a little over 12 weeks after planting, that is until November 10. At this time they averaged 12.7 inches in height, while the control, with exposure to normal daily length, averaged 15.1 inches in height. The plants in the A series were subjected to a daily exposure of 13½ hours during 10 weeks, from November 10 to January 19, at the end of which time they averaged 52.6 inches in height, while the control, with exposure to normal day length, averaged only 35.9 inches. The growth of these plants up to a little more than 24 weeks from planting is graphically shown in figure 5.

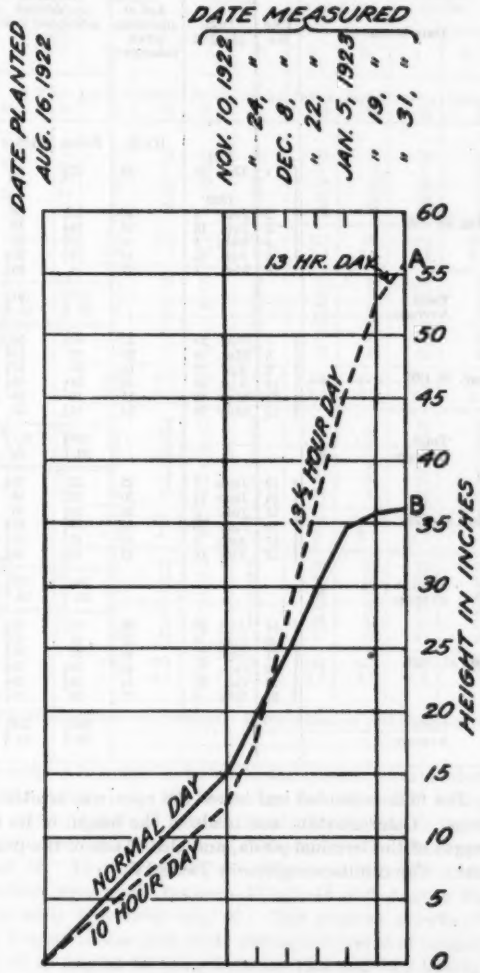


FIG. 5.—Average increase in height made by 3 plants each in cans No. 18, A and B series, under different light exposures.

EFFECT OF DAY LENGTH ON INTERNODAL LENGTH AND LEAF DIMENSIONS.

In order to determine the effect of day length on internodal length and leaf dimensions, the plants in cans No. 1 to 24, inclusive, were divided into four groups, cans No. 1 to 6, 7 to 12, 13 to 18, and 19 to 24, respectively. Each group was measured on the date on which its plants ranged from 12 to 22 weeks from planting. Prior to the taking of these measurements, the plants in the A series had uniformly received a 10-hour day length, and those in the B series, the normal day length. The tallest plant in each can was selected for measurement. Its height to the uppermost expanded leaf, number of nodes, and internodal length, are given in Table III.

TABLE III.—*Showing height and internodal length of tallest plants in cans No. 1 to 24, A and B series*

Date measured	Can No.	Date planted	Age of plantings when measured	Height to uppermost expanded leaf		Number of internodes included		Average internodal length, with stem below cotyledons considered as an internode	
				A	B	A	B	A	B
			Weeks	*Inches*	*Inches*			*Inches*	*Inches*
	1	1921 Dec. 21	22	27½	32	21	17	1.3	1.9
		1922							
May 24, 1922	2	Jan. 4	20	26½	36	19	19	1.4	1.9
	3	Jan. 18	18	24½	30	19	14	1.3	2.1
	4	Feb. 1	16	26½	31	15	14	1.8	2.2
	5	Feb. 15	14	24½	33¼	15	14	1.6	2.4
	6	Mar. 1	12	18	28¾	11	13	1.6	2.2
Total				147½	191½	100	91	9.0	12.7
Average				24.5	31.9	16.7	15.2	1.5	2.1
	7	Mar. 15	22	54½	65	30	29	1.8	2.2
	8	Mar. 29	20	48	71½	25	28	1.9	2.6
Aug. 16, 1922	9	Apr. 12	18	35	67¾	22	24	1.6	2.8
	10	Apr. 26	16	31½	46½	19	20	1.7	2.3
	11	May 10	14	16	38	12	15	1.3	2.5
	12	May 24	12	13½	23	10	12	1.4	1.9
Total				198½	311¾	118	128	9.7	14.3
Average				33.1	52	19.7	21.3	1.6	2.4
	13	June 7	22	33	55½	22	25	1.5	2.2
	14	June 21	20	28½	54	21	24	1.4	2.3
Nov. 8, 1922	15	July 5	18	26¾	44	18	24	1.5	1.8
	16	July 19	16	19½	42½	15	20	1.3	2.1
	17	Aug. 2	14	15½	28¾	13	15	1.2	1.9
	18	Aug. 16	12	10½	14½	11	12	1.0	1.2
Total				133½	239½	100	120	7.9	11.5
Average				22.2	39.9	16.7	20	1.3	1.9
	19	Aug. 30	22	48	46½	23	25	2.1	1.9
	20	Sept. 13	20	43	42½	22	21	2.0	2.0
Jan. 31, 1923	21	Sept. 27	18	33	33¾	19	18	1.7	1.9
	22	Oct. 11	16	30½	32½	17	16	1.8	2.0
	23	Oct. 25	14	24½	28½	13	14	1.9	2.0
	24	Nov. 8	12	23	21½	10	11	2.3	2.0
Total				202½	205½	104	105	11.8	11.8
Average				33.7	34.3	17.3	17.5	2.0	2.0

The fifth expanded leaf below the apex was arbitrarily chosen for leaf dimensions. Determination was made of the length of its midrib, number of pinnae, length of the terminal pinna, and also of one of the pair of pinnae midway of the leaf. The results are given in Table IV.

TABLE IV.—*Leaf measurements on tallest plant, fifth expanded leaf below apex cans No. 1 to 24, inclusive, A and B series*

Date measured	Can No.	Date planted	Age of plantings when measured	Length of midrib		Number of pinnae		Length of pinna midway of leaf		Length of terminal pinna	
				A	B	A	B	A	B	A	B
	1	1921 Dec. 21	*Weeks* 22	*Inches* 4½	*Inches* 6½	*Inches* 21	*Inches* 21	*Inches* 1½	*Inches* 2½	*Inches* 2½	*Inches* 2½
	2	1922 Jan. 4	20	4½	7½	21	19	2½	3½	2½	3½
May 24, 1922	3	Jan. 18	18	5	8	23	17	2	2½	2	2½
	4	Feb. 1	16	5½	6½	15	15	2½	2½	2½	2½
	5	Feb. 15	14	6	7½	17	17	2½	3	2½	2½
	6	Mar. 1	12	4½	6½	9	11	2½	3½	2½	3½
Total				29½	42½	106	100	13½	18½	14½	17½
Average				4.9	7.1	17.7	16.7	2.3	3.1	2.4	2.9
	7	Mar. 15	22	6½	8½	21	23	2½	2½	2½	2½
	8	Mar. 29	20	5½	8	21	21	2½	2½	2½	2½
	9	Apr. 12	18	5½	8½	19	23	2½	3½	2½	3½
Aug. 16, 1922	10	Apr. 26	16	6	8½	19	23	2½	2½	2½	*2½
	11	May 10	14	3½	6½	11	17	2½	3	2½	3
	12	May 24	12	2½	4½	7	11	1½	2½	1½	2½
Total				29½	44½	98	118	13½	17½	14½	16½
Average				4.9	7.4	16.3	19.7	2.3	2.9	2.4	2.8
	13	June 7	22	5½	5½	17	21	2½	2½	2½	2½
	14	June 21	20	4½	6½	19	21	1½	2½	1½	2½
	15	July 5	18	6½	8½	17	21	2½	2½	2½	2½
Nov. 8, 1922	16	July 19	16	4½	7½	13	21	2½	2½	2½	2½
	17	Aug. 2	14	3	5½	11	15	2	2½	2½	3
	18	Aug. 16	12	2½	3½	7	9	1½	2	2½	2½
Total				25½	36½	84	108	12½	15	13½	15½
Average				4.2	6	14	18	2	2.5	2.2	2.5
	19	Aug. 30	22	6½	5½	17	19	2½	2½	2½	2½
	20	Sept. 13	20	7½	7½	19	21	3	2½	2½	2½
	21	Sept. 27	18	6½	7½	17	19	2½	2½	2½	2½
Jan. 31, 1923	22	Oct. 11	16	6½	6½	17	17	2½	2½	2½	2½
	23	Oct. 25	14	4½	5½	11	13	2½	3	3½	3½
	24	Nov. 8	12	3½	4½	7	9	2	2½	2½	2½
Total				33½	36½	88	98	15½	16½	16½	16½
Average				5.6	6.1	14.7	16.3	2.6	2.7	2.8	2.7

*The pinna which should have been measured here was damaged. Entry is mean of that of leaf above and below.

Series B was greater than series A in height in inches to the uppermost expanded leaf in each instance in cans No. 1 to 18, inclusive, the difference being especially noticeable in the measurements of August 16 on plantings made from March 15 to May 24, and in the measurements of November 8 on plantings made from June 7 to August 16. In other words, the differences in height were pronounced on plantings which were made between March 15 and August 16, and on growth made up to early November (fig. 6). The greatest growth of any of the plants measured August 16 was that made during the period of longest days (the range from April 27 to August 15 being between 12.8 and 13.2 hours). In the measurements made January 31 on plantings of August 30 to November 8, and on growth made during the period of shortest days (the range from November 2 to January 31 being between 11 and 11.4 hours), the difference in height was found to be insignificant between the plants receiving a 10-hour daily length and their controls which were subjected to the normal day length.

The variations in the growth of the plants receiving a 10-hour day length would seem to indicate that, in addition to length of day, some other factor or factors influenced growth, such as difference in atmospheric moisture or temperature at the different seasons, or difference in the quality of sunlight, the sun being much higher in the sky at the hour at which the plants were brought from the dark chamber in summer.

Two factors account for the difference in height, namely, length of internode and number of nodes. In 22 of the 24 instances, the internodal length of the control plant exceeded that of the treated. In the graph illustrating this (fig. 7), the lines do not cross except in the last group, the measurements being for the period of shortest day length. That the difference was very pronounced for growth made in the period of greater day length was demonstrated by the growth of plants in cans No. 1 to 18, inclusive. In the case of plantings in cans No. 8

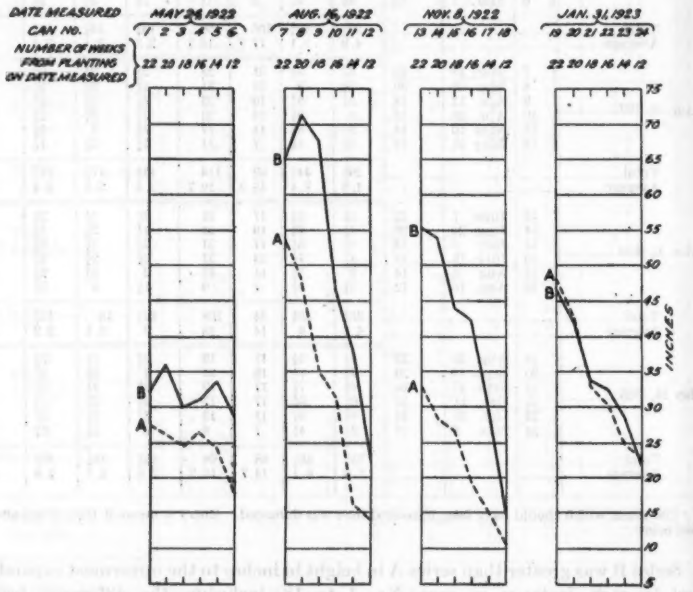


FIG. 6.—Height of tallest plant in cans No. 1 to 24, A and B series. A, day length reduced to 10 hours B, normal days

to 18, inclusive, made between the last of March and the middle of August, the control in each instance had more nodes than the treated plant, the average difference between control and treated being 2.8 nodes per plant. The others varied, their total measurements averaging only 0.7 node in difference between control and treated. In leaf measurements, the midrib of plants in the B series was longer than was true in case of the A series in 23 of the 24 instances, plants in can No. 19 being the exception.

Measurements were made of the fifth expanded leaf below the apex, this leaf presumably having developed, in most instances, approximately 4 to 6 weeks previously. Measurements of the midrib, made in May and August, showed a difference in length of 46 and 53 per cent, respectively, between the A and the B series. In the November measurement this difference was a trifle less pronounced amounting to 42 per cent. In the January measurements of leaves developed in the period of shortest days, this difference fell to 8 per cent.

That the number of pinnae also was affected by the day length would seem to be indicated in the count of pinnae of the plants in the A and the B series. In two instances, those of the A series had the greater number, in 5 the count was equal, and in 17 instances, plants of the B series had a greater number of pinnae than did those of the A series. The B series, with a normal day length, had a total of 13 per cent more pinnae than the A series, grown in a day of 10-hour length. This, however, was not borne out in measurements made January 19, and discussed later. (See Table IV.)

The length of the pinnae was decidedly affected by the day length. In length of pinna midway of leaf, the B series exceeded the A series in 21 of the 24 instances, equaled it in one, and was less than it in only two, these latter being in case of leaves which were measured January 31 and which had developed in the time of shortest day length. In the May, August, and November measurements, the difference between the A and the B series amounted to 37, 28, and 22 per cent, respectively, but in the January measurements this fell to 2 per cent. The difference in length of terminal pinna between the A series and the B series was

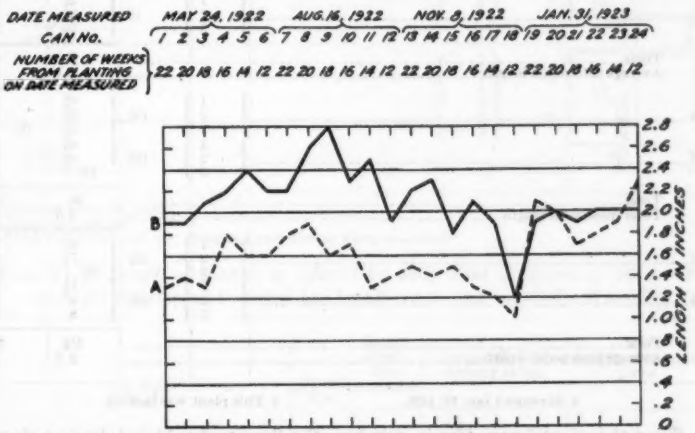


FIG. 7.—Average internodal length of tallest plant in cans No. 1 to 24, A and B series. A, day length reduced to 10 hours. B, normal day

decided, but not so pronounced as in the pinnae midway of the leaf. The B series exceeded the A series in 15 of the 24 instances, equaled it in 5, and was exceeded by the A series in only 4 instances, one of which was an estimated measurement in lieu of that of a damaged pinna, for which the mean of the leaves above and below was taken. The differences for the May, August, and November measurements amounted to 18, 19, and 13 per cent, respectively, while in the January measurements this fell to 2 per cent, as in the case of the midway pinna.

Of the controls for groups 1, 2, and 3, the plants in all cans to No. 13, inclusive, flowered in the autumn of 1922, for the time discontinuing further vegetative growth. On January 19, 1923, leaf measurements were made on all plants of which the controls in these three groups had not flowered, namely the plants in cans No. 14 to 18, inclusive, and on their controls. During the 10 weeks preceding this date, can No. 16 had received a day artificially shortened to 10 hours, cans No. 14 and 17, a day artificially lengthened to 12½ hours, and cans No. 15 and 18, all A series, a day lengthened to 13½ hours. In this period of 10 weeks, the normal day had shortened from 11.4 hours to 11 hours, and then lengthened to 11.2 hours.

In order to measure a leaf which would show as fully as possible the effect of the 10-week lighting period and at the same time be well-developed, the second expanded leaf below the apex was measured on each plant, and also the length of stem from the node below this leaf to the node above it. That the day length very decidedly affected internodal length is indicated by the data presented in Table V.

TABLE V.—*Internodal length produced under daily light exposures of 10 to 13½ hours for A series, and normal day length (11 to 11.2 hours), for B series*[a]

Can No.	Plant No.	Length of daily light exposure	Combined length of two internodes below uppermost expanded leaf	
		A	A	B
		Hours	*Inches*	*Inches*
16	1	10	2½	2½
	2		3½	1½
	3		2½	2½
Total			8	6½
Average internodal length			1.3	1.1
14	1	12½	4½	2½
	2		5½	1½
	3		5½	(b)
17	1	12½	6½	1½
	2		4½	2½
	3		(b)	3½
Total			26	11
Total internodal length			2.6	1.1
15	1	13½	6½	2½
	2		7½	2½
	3		(b)	2½
18	1	13½	7½	3½
	2		6	3½
	3		8	5½
Total			35½	19½
Average internodal length			3.5	1.6

a Measured Jan. 19, 1923. b This plant was lacking.

Since the plants were few in number, the figures should not be too closely interpreted. The greatest average internodal length for growth made by any group receiving normal day length amounted only to 1.6 inches, while under a 12½-hour day length, it amounted to 2.6 inches, and under a 13½-hour day length, to 3.5 inches. Although growth made under the 10-hour day length exceeded its own control, it fell within the range of the three controls. The longer days produced longer internodes.

The effect of day length on midrib length was most pronounced, as shown by Table VI.

Under daily light exposures of 10, 12½, and 13½ hours, the average midrib lengths were 5, 7, and 9 inches, respectively, while the average for their controls ranged from 4.6 to 5.5. inches. With the exception of one dying plant, every individual in the 13½-hour group exceeded in length of midrib every plant in the 12½-hour group, each of which in turn exceeded each of the plants of the 10-hour group. The longer days produced leaves with longer midribs.

The indication seen in the earlier measurements of the development of a greater number of pinnae in the longer day was not borne out by the count on these leaves. However, the number of plants was small. The treated plants averaged 19 pinnae for each group, while 2 controls averaged 20, and the third control, 21.

The effect of day length on pinna length was most pronounced, as shown by Table VII.

TABLE VI.—*Length of midrib of leaf as affected by daily light exposures of 10 to 13½ hours for A series, and normal day length (11 to 11.2 hours) for B series*[a]

Can No.	Plant No.	Length of daily light exposure	Length of midrib of second expanded leaf below apex	
		A	A	B
		Hours	*Inches*	*Inches*
16	1	10	4½	4½
	2		5	3½
	3		5½	5½
Total			15	13½
Average			5	4.6
14	1	12½	6½	4½
	2		6½	4½
	3		6½	(b)
17	1	12½	8½	4½
	2		7½	4½
	3		(b)	6½
Total			34½	23½
Average			7	4.7
15	1	13½	9	5½
	2		[c] 7½	4½
	3		(b)	4½
18	1	13½	9½	5½
	2		10	5½
	3		9½	7½
Total			44½	33½
Average			9	5.5

[a] Measured Jan. 19, 1923.
[b] Plant was lacking.
[c] Plant had wilted and was dying of a root disease when measured.

TABLE VII.—*Length of pinnae as affected by daily light exposures of 10 to 13½ hours for A series, and normal day length (11 to 11.2 hours) for B series*[a]

Can No.	Plant No.	Length of daily light exposure	Length of pinna midway of leaf		Length of terminal pinna	
		A	A	B	A	B
		Hours	*Inches*	*Inches*	*Inches*	*Inches*
16	1	10	1½	1½	2½	2½
	2		2	1½	2½	1½
	3		1½	1½	1½	1½
Total			5½	5½	6½	5½
Average			1.9	1.8	2.1	2.0
14	1	12½	2½	1½	2½	1½
	2		2½	1½	2½	1½
	3		2½	(b)	2½	(b)
17	1	12½	2½	2	2½	2½
	2		3	2½	2½	2½
	3		(b)	2½	(b)	2½
Total			13½	9½	12½	10½
Average			2.7	1.9	2.5	2.1
15	1	13½	3½	2½	[c] 2½	2½
	2		3½	1½	2½	1½
	3		(b)	2	(b)	2
18	1	13½	3½	2½	2½	2½
	2		3½	2½	2½	2½
	3		3½	2½	2½	2½
Total			17½	13	13½	13½
Average			3.5	2.2	2.8	2.3

[a] Measured Jan. 19, 1923.
[b] This plant was lacking.
[c] This pinna was diseased. The corresponding one on leaves above and below measured 3 and 3½ inches, respectively.

The pinnae midway of the leaves measured averaged in length for daily exposures of 10, 12½, and 13½ hours, 1.9, 2.7, and 3.5 inches, respectively, while the controls exposed to a normal short day, averaged in length from 1.8 to 2.2 inches. Similarly, but in a less pronounced degree, the terminal pinna was affected, the average lengths for the 10, 12½, and 13½ hour exposures being 2.1, 2.5, and 2.8 inches, respectively, and for their controls ranging from 2 to 2.3 inches.

These measurements show very definitely that a day length of 12½ or 13½ hours is much more favorable to leaf development than a day length of 10 or 11 hours, the longer day causing the development of a much larger leaf, longer in both midrib and pinnae. These measurements on plants grown under an artificially shortened and an artificially lengthened day explain the pronounced difference in appearance between the plants in the field in late fall and winter, with their slow growth, short internodes, and small leaves, and the plants in late spring, with their rapid growth, long internodes, and large leaves. This contrast is shown in Plate 2, B, on a branch obtained from row No. 16, planted July 19, 1922, and photographed May 9, 1923.

SUMMARY

The blossoming of *Tephrosia candida* was inhibited both by a day length shortened to 10 hours, and by a day length of 13.2 hours (length of the longest summer days in Mayaguez, P. R.).

Shortening the day from the long day of summer to a 12-hour length promptly induced blossoming, whereas a continuation of exposure to the long summer days inhibited it.

Under a day length artificially protracted to 13½ hours for 10 weeks, buds failed to appear, but on shortening the day length they promptly appeared.

Under exposure to a maximum day length of 12½ hours, later reduced to 12 hours, the plants displayed much less tendency to come into blossom than was the case when reduction was made from a longer day.

There was still less tendency to blossom when the day, instead of being shortened, was lengthened from 10 to 12 hours.

While blossoming may occur under a 12-hour day, whether the preceding days have been too short or too long for blossoming, the impulse to blossom apparently is much more pronounced when the preceding days have been too long rather than too short, days of too great a length followed by shorter days quickly inducing the reproductive stage.

Although autumn is the normal blossoming season for *T. candida*, heavy blossoming was induced in April through artificial manipulation of the length of light exposure or day length.

Day length not only determines the blossoming season for *T. candida*, but it also affects its growth in a pronounced and decided manner, the longer days producing growth with longer internodes and larger leaves.

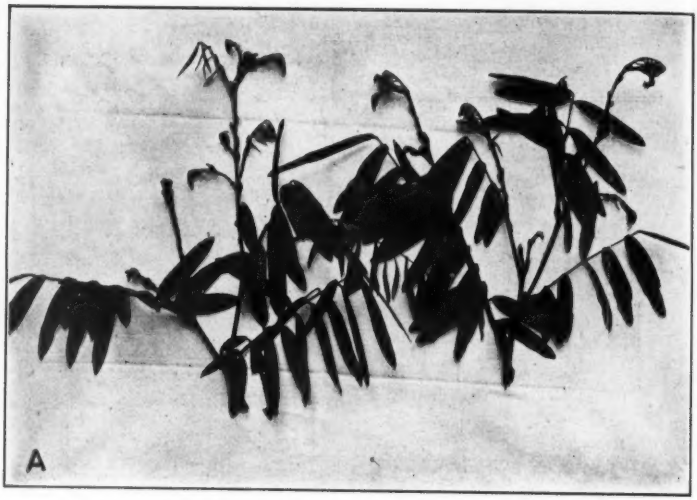
PLATE 1

A.—Simultaneous blossoming of rows up to No. 13 planted June 7 and earlier. No blossoms on later plantings. Photographed October 28, 1922.

B.—Another section of same field photographed on same date, showing rows No. 7 to 12 in simultaneous blossoming though planted at two-week intervals.

A

B


A

B

on, D. C.

PLATE 2

A.—Growth to be seen in midsummer, the reproductive stage having been started by the spring days of intermediate length, then arrested by the long days of summer, with a resumption of vegetative growth. Photographed August 1, 1923.

B.—Normal vegetative development, showing the short leafed, short internodal growth made in the shorter days, in contrast with the later growth of large leaves, and long internodes typical of growth made in the longer days. Photographed May 9, 1923.

PLATE 3

A.—Growth and flowering under normal day length, all plants either budded, in blossom, or with young seed pods. Photographed October 27, 1922.

B.—Growth under a 10-hour day. No indication of blossoming. Planted on same dates as B plants correspondingly numbered. Photographed October 27, 1922.

B

A

A
16A
17A
18A
16B
17B
18B

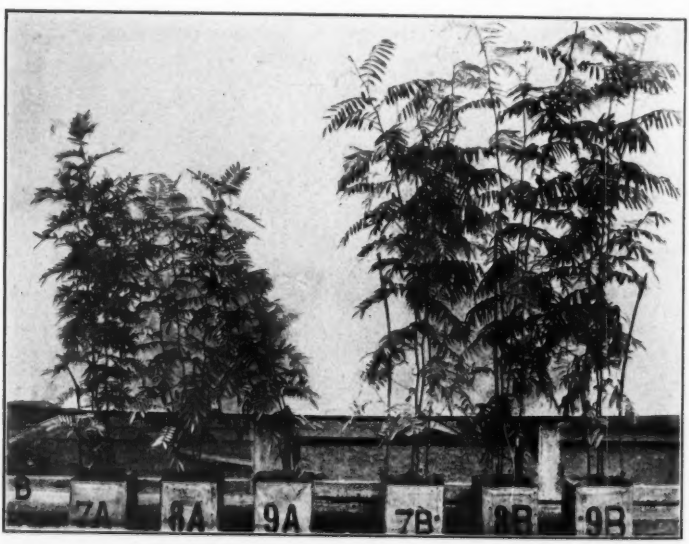

B
7A
8A
9A
7B
8B
9B

PLATE 4

A.—Plants in can No. 18A, brought into blossom out of season by exposure to 13½-hour day, followed by reduction in day length. Plants in cans No. 17A, which had received a 12½-hour day and in No. 16A, a 10-hour day, and in B cans, a normal day length, all without buds or blossoms. Photographed April 19, 1923.

B.—Difference in height attributable to difference in length of day. Series A, grown under a 10-hour light exposure, and series B, under normal day length. Photographed August 18, 1922.

ANTINEURITIC VITAMIN IN POULTRY FLESH AND EGGS[1]

By RALPH HOAGLAND, *Senior Biochemist, Biochemic Division,* and ALFRED R. LEE, *Poultryman, Animal Husbandry Division, Bureau of Animal Industry, United States Department of Agriculture*

POULTRY AND EGGS IN THE DIETARY

The importance of vitamins in the human dietary is so well established that the nutritive value of a food product must now be judged not only by the usual standards but by its vitamin content as well. It does not follow, of course, that because a foodstuff is deficient in one or even all of the vitamins that it is of low nutritive value. Indeed, several of our most important foodstuffs are practically devoid of vitamins. And, on the other hand, a food product is not necessarily of high nutritive value solely because of its richness in one or more of the vitamins; but a food that is rich in vitamins, as well as having a high nutritive value in other respects, is greatly to be prized. What is needed, of course, is adequate information concerning the vitamin content of all our food products, so that each may be used in proper combination with others so as always to insure an abundance of each of the vitamins in the diet.

Poultry occupies an important place in the dietary of the American people, particularly on the farm, but it is highly regarded by all classes of people. Poultry flesh is generally considered to have as high nutritive value as beef, pork, or mutton. The per capita consumption of poultry in this country in 1919 is estimated as 11.5 pounds. For the same year, the estimated per capita consumption of beef and veal was 65.7 pounds; pork, excluding lard, 68.6 pounds, and mutton and lamb 5.8 pounds.

Eggs are one of our most important foods. Their high nutritive value is well established and no other food can quite take their place. Not only are they used extensively as such as a food, but they also enter into the preparation of a great variety of food products. According to the census the number of eggs produced on farms in the United States in 1919 was 1,654,044,932 dozens. For the same year exports and imports, including dried and frozen eggs, were practically equal. After making deductions for eggs used for hatching and for loss of eggs due to breakage and spoilage, it is estimated that the per capita consumption of eggs in this country in 1919 was 159.

PREVIOUS INVESTIGATIONS

There seems to be no information in the literature concerning the vitamin content of poultry flesh, although it is possible that the report of some investigation may have been overlooked.

The vitamin B content of eggs has been studied by a number of investigators, some having determined the antineuritic value by means of feeding tests with

[1] Received for publication March 17, 1924.

pigeons, while others have ascertained the value of eggs as a source of vitamin B for growth in young rats. Following are the opinions of several authorities concerning the value of eggs as a source of vitamin B:

McCarrison (*4, p. 18*).[1] "This vitamin is widely distributed throughout natural foodstuffs. Its richest sources are the germs of seeds, eggs, yeast, wheat and rice bran, peas, beans, lentils, and cellular organs (such as liver, brain, sweetbreads, fish-roe, kidneys, and heart muscle.)"

Sherman and Smith (*6, p. 86*). "Eggs. There is probably as high a concentration of vitamin B in the egg, or at least in the egg yolk, as in any part of the body. This is indicated both by the experiments of Cooper upon prevention of polyneuritis and those of Osborne and Mendel upon the support of growth. The latter results have apparently not yet been published in full, but are referred to in terms which would imply that the solids of eggs and of milk have about equal proportions of the water-soluble vitamin."

The work of Cooper (*1*) deserves special mention because it was carried on by methods very similar to those employed in the investigation that is to be reported in this paper. Cooper determined the antineuritic value of both raw and cooked egg yolk when fed to pigeons together with polished rice. Raw egg yolk was fed daily to groups of 2 pigeons each, in quantities varying from 1 to 10 gm. for each bird. It was found that when 5 gm. of raw egg yolk were fed daily to each of 2 pigeons that they did not develop polyneuritis during a period of 55 days, but they lost greatly in weight to the extent of 30.7 and 32.1 per cent, respectively. Ten grams of raw egg yolk in the daily ration of each of two pigeons protected them against polyneuritis during a period of 55 days, but they had lost 3 and 7.5 per cent, respectively, in weight.

Cooked egg yolk had a similar value to the raw product. Six grams of cooked egg yolk in the daily ration of each of 2 pigeons protected them against polyneutritis for 50 days, but they had lost 12.2 and 19 per cent, respectively, in weight.

In conclusion, Cooper, states:

Egg yolk exceeds all the other foodstuffs examined of animal origin in antineuritic value, three grams daily added to the rice diet being sufficient to prevent polyneuritis Its capacity for preventing this disease is not measurably altered by boiling for four minutes.

Osborne and Mendel (*5*) report that—

Rats weighing 100 gm. living on a standard food mixture, of which they consumed about 50 gm. per week, have required not less than 0.5 gm. of dried egg yolk a day (equivalent to 10 per cent of this food mixture) fed apart from the rest of the ration, to secure even an approximation to the normal rate of growth; and in every case the rate of gain has increased when 0.2 gm. of dried brewers' yeast replaced the egg-yolk preparation.

In conclusion the authors state in part:

The content of egg yolk in vitamin B is not large, a daily intake of at least 1.5 gm. of the fresh yolk being required when it furnishes the sole source of vitamin B to a 100-gm. rat. The whole egg is accordingly not exceptionally rich in vitamin B when contrasted with the foods already investigated. Judged by the comparative trials on rats, the average sized hen's egg is equivalent to about 150 c. c. of cow's milk, or, a quart milk and six or seven eggs of the average sort have an approximately equivalent vitamin B value.

EXPERIMENTAL WORK

The purpose of this investigation was to determine the vitamin B (antineuritic vitamin) content of dried poultry flesh and eggs as measured by the quantity of either product, required in a ration with polished rice to protect a pen of four pigeons against both development of polyneuritis and loss in weight during a test period of 56 days.

The methods employed are essentially the same as those previously employed by one of the writers (*2,3*) in a study of the antineuritic properties of the edible tissues of the ox, sheep, and hog. The feeding tests with pigeons were conducted by Abraham Balter, formerly laboratory aid in the Biochemic Division.

[1] Reference is made by number (italic) to "Literature cited," p. 472.

DESCRIPTION OF POULTRY AND EGGS TESTED

Chickens

Rhode Island Red, Barred Plymouth Rock, and White Leghorn chickens were hatched in April, 1922, out of good breeding stock. They were raised in grass fields where they had free range and secured an unlimited amount of green feed. They received practically the same feed from date of hatch until they were killed at approximately four months of age. As small chicks, they were first fed a mixture of boiled eggs and rolled oats with a commercial baby-chick scratch feed. At the age of two weeks the use of the egg-oatmeal mixture was discontinued and they were given a mash made up in parts by weight as follows:

4 parts rolled oats.
2½ parts meat scrap.
2 parts corn meal.
2 parts bran.
1 part middlings.
½ part ground bone
1 per cent salt.

This mash was kept in hoppers before the chickens at all times until they were killed. As soon as they were large enough to eat ordinary grain, at about 8 weeks of age, the baby-chick scratch feed was omitted and a feed consisting of equal parts of cracked corn and wheat was substituted.

The Rhode Island Red and Barred Plymouth Rock chickens weighed about 3½ pounds each when killed, and the White Leghorns weighed about 2½ pounds. All the chickens in the three lots used were cockerels.

Hens

Rhode Island Red, Barred Plymouth Rock, and White Leghorn hens were used in tests of the flesh of mature fowls. The average dressed weights of the hens in each of the three lots were 5, 5½, and 3½ pounds, respectively. Some of the hens were 1½ years old and others 2½ years old, but all had been given practically the same kinds of feeds throughout their lives. All had been fed the same scratch feed and but slightly different mashes, substantially as follow:

Mash	*Scratch Feed*
10 parts bran.	2 parts cracked corn.
10 parts middlings.	1 part wheat
10 parts ground oats.	1 part oats.
45 parts corn meal.	
25 parts meat scrap.	

The proportions of the several constituents, other than the meat scrap, varied somewhat in the different mashes, but all the feeds were used in each mash. Each lot of hens was kept in a good-sized yard where there was more or less green feed either in the form of grass or as a growing crop of young oats, wheat, or rape. In addition, each pen of hens was fed three times weekly as much sprouted oats as they would consume. Approximately equal parts of mash and scratch feed were fed daily.

Turkeys, Ducks, and Guinea Fowl

The above-named birds were purchased in January, 1923, from a local produce dealer. They had been shipped alive from Maryland and Virginia farms and were killed at the time of purchase. The turkeys consisted of 4 fat hens weighing 11½, 11½, 12, and 15½ pounds, respectively. The ducks consisted of 15 common farm ducks of fair quality. The guinea fowl were fair-quality birds weighing about 2½ pounds each, the lot containing 22 birds.

Hens' Eggs

The eggs used in the tests for vitamin B were laid by hens kept under similar conditions and fed the same feeds as those that were killed. The eggs were collected in September, 1922, when the hens were receiving a considerable quantity of green feed. At that time the hens were nearing the end of their laying season.

METHOD OF DRYING POULTRY FLESH AND EGGS

The flesh, fat, and skin of the frying chickens were ground together, but the muscle tissue of the hens and other birds was separated from the skin and from the fat, as far as practicable, before grinding. The ground flesh was thoroughly mixed with water and toluol in the proportion of 800 grams, 400 cubic centimeters, and 40 cubic centimeters, respectively, and the mass was spread out in shallow pans and dried in an oven in a current of air at a temperature that did not exceed 60° C. The tissue became dry in 18 to 20 hours, after which it was ground, transferred to bottles, and held in cold storage until needed.

The eggs were separated from the shells, thoroughly beaten, spread out in a thin layer in shallow pans, and dried in a current of air at a temperature of 60° C.

FEEDING TESTS WITH RATIONS VERY DEFICIENT IN ANTINEURITIC VITAMIN

In order to judge the antineuritic value of a ration containing the product to be tested, it is necessary to have for comparison the results of other experiments conducted in the same manner in which the pigeons have been fed rations practically devoid of antineuritic vitamin. In Table I are reported the results of a number of such tests previously reported by one of the writers (2, 3).

Table I.—*Feeding tests with rations very deficient in antineuritic vitamin*

Rations		Pigeon No.	Initial weight	Final weight	Change in weight	Survival period	Result
Ingredients	Per cent						
Pen 1:			*Grams*	*Grams*	*Per cent*	*Days*	
Autoclaved rice	100	2,061	366	348	−4.9	18	Polyneuritis.
		2,062	362	284	−21.5	18	Do.
		2,064	316	255	−19.3	28	Do.
		2,065	425	303	−28.7	25	Do.
Average			367	298	−18.6	22	
Pen 2:							
Autoclaved rice	100	249	425	383	−9.9	17	Polyneuritis.
		250	470	273	−41.9	46	Do.
		251	389	282	−27.5	24	Do.
		252	419	306	−27.0	24	Do.
Average			426	311	−26.6	28	
Pen 3:							
Autoclaved rice	76	2,066	305	280	−8.2	21	Polyneuritis.
Autoclaved beef	15	2,067	362	320	−11.6	21	Do.
Cod-liver oil	5	2,068	304	256	−15.8	27	Do.
Ash mixture	4	2,069	300	225	−25.0	29	Do.
Average			318	270	−15.2	25	
Pen 4:							
Autoclaved rice	76	245	379	329	−13.2	21	Polyneuritis.
Autoclaved beef	15	246	396	275	−30.6	42	Do.
Butterfat	5	247	377	304	−19.4	28	Do.
Ash mixture	4	248	335	311	−7.2	21	Do.
Average			372	305	−17.6	28	

From the data presented in Table I it will be noted that the average survival period of the pigeons in pens 1 and 2 receiving only autoclaved rice was 25 days, while the average survival period of the pigeons in pens 3 and 4 receiving rice supplemented with dried autoclaved beef, cod-liver oil or butterfat, and ash mixture was practically the same, or 26½ days. The average loss in weight of the birds in pens 3 and 4 was somewhat less than that of the pigeons in pens 1 and 2, being 16.4 per cent as compared with 22.6 per cent. The average survival period of all the pigeons in pens 1 to 4, inclusive, was 26 days, and the average loss in weight was 19.5 per cent.

ANTINEURITIC VITAMIN IN THE FLESH OF FRYING CHICKENS

In Table II are presented the results of feeding tests with the dried flesh of frying chickens of three breeds, viz, Rhode Island Red, Barred Plymouth Rock, and White Leghorn. Each lot of dried flesh was fed to 4 pens of 4 pigeons each, the proportions of flesh in the several rations being 5, 10, 25, and 30 per cent. The data in the table show that each of the three lots of poultry (fryers) flesh had a rather low antineuritic value. The rations containing 5 and 10 per cent respectively, had no higher antineuritic value than the check rations reported in Table I, while the addition of even 25 or 30 per cent of the poultry flesh to the other rations gave them only slightly higher values. In no case did a ration containing even 30 per cent of fryer flesh protect an entire pen of pigeons against polyneuritis for 56 days, the maximum average survival period being 34 days. Only one pigeon (No. 154, pen 8) out of the 48 birds reported in Table II survived the test period of 56 days, and this bird was much emaciated at the close, having lost 35.2 per cent in weight.

TABLE II.—*Antineuritic value of flesh of frying chickens*

Ration		Pigeon No.	Change in weight	Survival period	Result
Ingredients	Per cent				
Pen 5:			*Per cent*	*Days*	
Rhode Island Red, fryer flesh.	5	2080	−20.0	20	Polyneuritis.
		2081	−32.7	35	Extreme emaciation; experiment discontinued.
Autoclaved rice	95	2082	−15.3	19	Polyneuritis.
		2083	−17.6	21	Do.
Average			−21.4	24	
Pen 6:					
Rhode Island Red, fryer flesh.	10	2084	−26.4	17	Polyneuritis.
		2085	−9.3	21	Do.
Autoclaved rice	90	2086	−15.5	21	Do.
		2087	−14.7	29	Do.
Average			−16.5	22	
Pen 7:					
Rhode Island Red, fryer flesh.	25	148	−20.2	52	Died.
		149	−12.8	18	Polyneuritis.
Autoclaved rice	75	150	−16.9	30	Do.
		151	−21.3	36	Died.
Average			−17.8	34	
Pen 8:					
Rhode Island Red, fryer flesh.	30	152	−26.5	35	Polyneuritis.
		153	−22.6	29	Died.
Autoclaved rice	70	154	−35.2	56	Emaciated at end of test.
		1259	−17.7	17	Died.
Average			−25.5	34	
Pen 9:					
Barred Plymouth Rock fryer flesh.	5	2089	−18.8	17	Polyneuritis.
		2091	−13.3	17	Do.
Autoclaved rice	95	2092	−29.0	21	Do.
		2093	−29.7	22	Died.
Average			−22.7	19	

TABLE II.—*Antineuritic value of flesh of frying chickens*—Continued

Ration		Pigeon No.	Change in weight	Survival period	Result
Ingredients	Per cent				
Pen 10:			*Per cent*	*Days*	
Barred Plymouth Rock, fryer flesh.	10	2094	−38.0	35	Extreme emaciation; experiment discontinued.
Autoclaved rice	90	2095	+4.5	14	Polyneuritis.
		2096	−5.7	13	Do.
		2097	−21.3	24	Do.
Average			−15.1	22	
Pen 11:					
Barred Plymouth Rock, fryer flesh.	25	156	−41.2	34	Died.
		157	−4.9	25	Polyneuritis.
Autoclaved rice	75	158	−20.7	26	Do.
		159	−14.2	34	Do.
Average			−20.3	30	
Pen 12:					
Barred Plymouth Rock, fryer flesh.	30	160	−12.4	28	Polyneuritis.
		161	(a)	24	Do.
Autoclaved rice	70	162	−10.9	32	Died.
		163	−15.1	30	Polyneuritis.
Average			−12.8	29	
Pen 13:					
White Leghorn, fryer flesh	5	2057	−17.5	25	Polyneuritis.
		2058	−24.4	20	Died.
Autoclaved rice	95	2059	−9.9	17	Polyneuritis.
		2060	−11.1	14	Do.
Average			−15.7	19	
Pen 14:					
White Leghorn, fryer flesh	10	2098	−9.6	22	Polyneuritis.
		2099	−12.2	17	Do.
Autoclaved rice	90	2100	−21.5	17	Do.
		190	−37.3	35	Extreme emaciation; discontinued experiment.
Average			−20.2	23	
Pen 15:					
White Leghorn, fryer flesh	25	164	−5.8	24	Polyneuritis.
		165	−26.7	50	Died.
Autoclaved rice	75	166	−21.3	29	Polyneuritis.
		167	−12.0	20	Do.
Average			−16.5	31	
Pen 16:					
White Leghorn, fryer flesh	30	168	−15.9	25	Polyneuritis.
		169	−18.7	45	Died.
Autoclaved rice	70	170	−8.6	22	Polyneuritis.
		171	−24.1	42	Do.
Average			−16.8	34	

[a] Bird's crop congested, did not weigh.

ANTINEURITIC VITAMIN IN THE FLESH OF HENS

In Table III are shown the results of feeding tests with the dried flesh of Rhode Island Red, Barred Plymouth Rock, and White Leghorn hens as the source of vitamin B in the rations. The percentages of dried flesh in the several rations ranged from 15 to 30. The results of these experiments show that the flesh of each of the three lots of hens had a very low antineuritic value. The pigeons in pen 20 which were fed a ration containing 15 per cent of Rhode Island Red hen flesh show the maximum survival period, 28 days, while those in pen 18 which were fed a ration containing 20 per cent of Barred Plymouth Rock hen flesh show the minimum average survival period of 19 days. Not a pigeon survived the test period of 56 days, the maximum survival period for an individual bird being 37 days. All pigeons receiving the hen-flesh rations lost in weight, the individual losses ranging from 3.7 to 41.4 per cent, and the average pen losses from 15.1 to 28.1 per cent.

On the whole, it appears that the flesh of the hens had an appreciably lower content of the anitneuritic vitamin than did that of the frying chickens. This difference is probably due to the fact that the young chickens were on free range and received a greater abundance of green feed than the hens which were confined in yards, although the latter received a certain amount of green feed.

TABLE III.—*Antineuritic value of hens' flesh*

Ration		Pigeon No.	Change in weight	Survival period	Result
Ingredients	Per cent				
			Per cent	*Days*	
Pen 17:					
Barred Plymouth Rock, hen flesh	15	109	−24.5	17	Polyneuritis.
		110	−18.4	16	Do.
Autoclaved rice	85	111	−41.4	26	Died.
		112	−27.7	28	Polyneuritis.
Average			−28.0	22	
Pen 18:					
Barred Plymouth Rock, hen flesh	20	113			Discarded, poor condition.
		114	−11.6	16	Polyneuritis.
Autoclaved rice	80	115	−31.7	21	Do.
		116	−26.5	21	Do.
Average			−23.3	19	
Pen 19:					
Barred Plymouth Rock, hen flesh	30	213	−28.6	35	Polyneuritis.
		214	−24.1	37	Do.
Autoclaved rice	70	215	−18.6	18	Do.
		216	−7.6	17	Do.
Average			−19.7	27	
Pen 20:					
Rhode Island Red, hen flesh	15	117			Accidental death.
		118	−23.4	24	Polyneuritis.
Autoclaved rice	85	119	−17.9	23	Do.
		120	−31.6	37	Do.
Average			−24.3	28	
Pen 21:					
Rhode Island Red, hen flesh	20	121	−18.2	16	Polyneuritis
		122	−9.7	18	Do.
Autoclaved rice	80	123	−33.4	33	Do.
		124	−33.0	23	Do.
Average			−23.6	23	
Pen 22:					
Rhode Island Red, hen flesh	25	201	−16.0	22	Polyneuritis.
		202	−25.5	21	Do.
Autoclaved rice	75	203	−18.1	20	Do.
		204	−19.2	26	Do.
Average			−19.7	22	
Pen 23:					
Rhode Island Red, hen flesh	30	205			Poor condition, discarded.
		206	−22.5	28	Polyneuritis.
Autoclaved rice	70	207	−21.7	25	Do.
		208	−16.4	17	Do.
Average			−20.2	23	
Pen 24:					
White Leghorn, hen flesh	15	125	−14.2	27	Polyneuritis.
		126	−26.4	35	Do.
Autoclaved rice	85	127	−25.6	24	Do.
		128	−7.9	23	Do.
Average			−18.5	27	
Pen 25:					
White Leghorn, hen flesh	20	129	−25.0	32	Polyneuritis.
		130	−3.7	16	Do.
Autoclaved rice	80	131	−31.8	19	Do.
		132			Escaped.
Average			−20.2	22	
Pen 26:					
White Leghorn, hen flesh	25	217	−37.1	35	Polyneuritis.
		218	−29.3	24	Do.
Autoclaved rice	75	219			Died from injury.
		220	−18.0	21	Polyneuritis.
Average			−28.1	27	
Pen 27:					
White Leghorn, hen flesh	30	221	−17.1	24	Polyneuritis.
		222	−20.4	24	Do.
Autoclaved rice	70	223	−12.1	26	Do.
		224	−10.7	24	Do.
Average			−15.1	25	

ANTINEURITIC VITAMIN IN FLESH OF TURKEYS, DUCKS, AND GUINEA FOWL

The results of the feeding tests with the dried flesh of turkeys, ducks, and guinea fowl are reported in Table IV. Each kind of flesh was fed only to one pen of pigeons, 30 per cent of the flesh being used in each ration. The data presented in this table show that the turkey flesh had a rather low antineuritic value, approximately the same as that of the frying chickens reported in Table II. The average survival period with the turkey flesh was 35 days and the loss in weight 23.7 per cent. All the pigeons receiving the ration containing 30 per cent of turkey flesh developed polyneuritis during the test period of 56 days.

The guinea-fowl flesh had a somewhat higher antineuritic value than the turkey flesh, the average survival period of the pen of pigeons receiving a ration containing 30 per cent of the guinea-fowl flesh being 44 days, the maximum survival period 49 days, and the average loss in weight 22 per cent.

The duck flesh had the highest antineuritic value of any of the lots of poultry flesh tested. The ration containing 30 per cent of dried duck flesh fully protected 4 pigeons against polyneuritis during the test period of 56 days. Two pigeons lost 6.3 and 10.7 per cent in weight, but the other two gained 3.3 and 9.8 per cent, the average change being a loss of 1 per cent.

TABLE IV.—*Antineuritic value of turkey, duck, and guinea-fowl flesh*

Ration		Pigeon No.	Change in weight	Survival period	Result
Ingredients	Per cent				
Pen 28:			*Per cent*	*Days*	
Turkey flesh	30	237	−16.7	32	Polyneuritis.
Autoclaved rice	70	238	−19.3	28	Do
		239	−34.5	41	Do.
		240	−24.2	39	Do.
Average			−23.7	35	
Pen 29:					
Duck flesh	30	241	−10.7	56	Fair condition at end of test.
		242	+9.8	56	Good condition at end of test.
Autoclaved rice	70	243	+3.3	56	Do.
		244	−6.3	56	Fair condition at end of test.
Average			−1.0	56	
Pen 30:					
Guinea fowl flesh	30	233	−16.9	39	Polyneuritis.
		234	−20.9	49	Do.
Autoclaved rice	70	235	−29.0	41	Do.
		236	−21.0	48	Do.
Average			−22.0	44	

ANTINEURITIC VITAMIN IN HENS' GIZZARDS AND LIVERS

In Table V are reported the antineuritic values obtained for the dried gizzards and livers from hens. The data presented show that the gizzards had a very low antineuritic value, the average survival period of the two pens of birds receiving rations containing 15 and 20 per cent of dried gizzards being only 21 and 22 days, respectively.

The hens' livers had a fairly high antineuritic value, the average survival period of the pen of pigeons receiving the ration containing 15 per cent of dried

liver being 38 days, and the average loss in weight only 4.4 per cent. One bird survived the test period of 56 days, having gained 12.5 per cent in weight, while the three others lost in weight and developed polyneuritis.

The ration which contained 20 per cent of dried hens' liver fully protected a pen of 3 pigeons against polyneuritis and loss in weight for 56 days. Only 3 pigeons were used in this pen on account of the limited supply of hens' livers.

TABLE V.—*Antineuritic value of hens' gizzards and livers.*

Ration		Pigeon No.	Change in weight	Survival period	Result
Ingredients	Per cent				
Pen 31:			*Per cent*	*Days*	
Hens' gizzards	15	133	−12.3	27	Polyneuritis.
		134	−24.7	24	Do.
Autoclaved rice	85	135	−8.8	17	Do.
		136	−25.5	16	Do.
Average			−17.8	21	
Pen 32:					
Hens' gizzards	20	137	−12.9	25	Polyneuritis
		138	−13.8	20	Do.
Autoclaved rice	80	139	−9.7	20	Do.
		140			Escaped.
Average			−12.1	22	
Pen 33:					
Hens' liver	15	141	+12.5	56	Good condition at end of test.
		142	−5.6	32	Polyneuritis.
Autoclaved rice	85	143	−16.7	44	Do.
		144	−7.7	19	Do.
Average			−4.4	38	
Pen 34:					
Hens' liver	20	145	0.0	56	Good condition at end of test
		146	+4.8	56	Do.
Autoclaved rice	80	147	+4.1	56	Do.
Average			+3.0	56	

ANTINEURITIC VITAMIN IN HENS' EGGS

In Table VI are reported the antineuritic values obtained for White Leghorn, Barred Plymouth Rock, and Rhode Island Red eggs. Each lot of dried eggs was fed to 4 pens of 4 pigeons each. The results of these experiments show that the eggs from each of the three breeds of chickens had a rather low antineuritic value. The average survival periods of the pigeons getting rations containing 25 and 30 per cent, respectively, of the eggs from each breed of chickens were as follows: White Leghorn, 33 days; Barred Plymouth Rock, 31 days, and Rhode Island Red, 27 days, while the average losses in weight were 11.5, 8.5, and 7.3 per cent, respectively. The rations containing the smaller percentages of eggs had about the same antineuritic values as the check rations in Table I, while the rations containing as much as 25 or 30 per cent of eggs had slightly higher values. Only 2 pigeons out of the 48 that were fed the egg rations survived the test period of 56 days; one was in fair condition at the close, while the other was greatly emaciated. It is to be noted, however, that while the average survival period of the pigeons receiving rations containing 30 per cent of dried eggs are not high, yet the average losses in weight are relatively low.

TABLE VI.—*Antineuritic value of raw hens' eggs*

Ration		Pigeon No.	Change in weight	Survival period	Result
Ingredients	Per cent				
Pen 35:			*Per cent*	*Days*	
White Leghorn eggs	5	1,201	−32.9	25	Polyneuritis.
		1,202	−27.2	17	Do.
Autoclaved rice	95	1,205	−28.8	29	Do.
		1,206	−28.0	24	Do.
Average			−29.2	24	
Pen 36:					
White Leghorn eggs	10	1,208	−30.0	29	Polyneuritis.
		1,209	−23.9	25	Do.
Autoclaved rice	90	1,210	+6.1	21	Do.
		1,211	−17.8	24	Do.
Average			−16.4	25	
Pen 37:					
White Leghorn eggs	25	172	−4.1	20	Polyneuritis
		173	−25.3	29	Do.
Autoclaved rice	75	174	−19.5	33	Do.
		175	−5.5	27	Do.
Average			−13.6	27	
Pen 38:					
White Leghorn eggs	30	176	−2.5	56	Fair condition at end of test.
		177	−15.4	24	Polyneuritis.
Autoclaved rice	70	178	−10.3	36	Do.
		179		[a] 11	Died, cause unknown.
Average			−9.4	39	
Pen 39:					
Barred Plymouth Rock eggs	5	1,213	−20.8	29	Polyneuritis.
		1,214	−37.0	35	Extreme emaciation, discontinued.
Autoclaved rice	95	1,215	−9.5	18	Polyneuritis.
		1,216	−25.4	24	Do.
Average			−23.2	27	
Pen 40:					
Barred Plymount Rock eggs	10	1,217	−2.1	24	Polyneuritis.
		1,218	+2.6	17	Do.
Autoclaved rice	90	1,219	+2.3	17	Do.
		1,220	−22.2	31	Do.
Average			−4.9	22	
Pen 41:					
Barred Plymouth Rock eggs	25	180	−10.4	29	Polyneuritis.
		181	−8.4	49	Do.
Autoclaved rice	75	182	−19.2	35	Do.
		183	−15.7	17	Do.
Average			−13.4	33	
Pen 42:					
Barred Plymouth Rock eggs	30	184	−6.0	24	Polyneuritis.
		185	−2.6	26	Do.
Autoclaved rice	70	186	−7.6	45	Do.
		187	+2.0	22	Do.
Average			−3.6	29	
Pen 43:					
Rhode Island Red eggs	15	101	−16.9	30	Polyneuritis.
		102	−12.3	20	Do.
Autoclaved rice	85	103	−13.0	24	Do.
		104	−21.8	37	Do.
Average			−16.0	28	
Pen 44:					
Rhode Island Red eggs	20	105	+1.1	30	Polyneuritis.
		106	−13.2	7	Do.
Autoclaved rice	80	107	−9.8	37	Do.
		108	−15.8	48	Do.
Average			−9.4	31	
Pen 45:					
Rhode Island Red eggs	25	188	−13.3	29	Polyneuritis.
		189	−35.4	56	Emaciated at end of test.
Autoclaved rice	75	190	+1.3	21	Polyneuritis.
		191	−2.2	15	Do.
Average			−12.7	30	
Pen 46:					
Rhode Island Red eggs	30	192	−5.2	25	Polyneuritis.
		193	−1.7	24	Do.
Autoclaved rice	70	194	−5.1	17	Do.
		195	+0.6	30	Do.
Average			−2.9	24	

[a] Not included in average.

EFFECT OF COOKING UPON ANTINEURITIC VITAMIN IN EGGS

White Leghorn eggs were cooked in boiling water for approximately 7 minutes and then cooled in a stream of cold water. The contents of the eggs were separated from the shells, ground in a meat grinder, dried in a current of air at a temperature below 60° C., and then ground in a burr mill. The dried eggs were mixed with autoclaved rice in two proportions and the antineuritic values of the rations are reported in Table VII.

By referring to Table VI, pen 38, it will be noted that the average survival period of that pen of birds receiving a ration containing 30 per cent of dried raw White Leghorn eggs is 39 days, while the average survival period of the pigeons in pen 48 that were fed a ration containing 30 per cent of dried cooked White Leghorn eggs is practically the same, or 40 days. The pigeons receiving 30 per cent of the raw eggs lost an average of only 9.4 per cent in weight, while those that were fed the same proportion of cooked egg lost an average of 19.2 per cent. It appears, then, that the antineuritic value of the eggs was slightly reduced by the method of cooking employed.

TABLE VII.—*Antineuritic value of dried cooked hens' eggs.*

Ration					
Ingredients	Per cent	Pigeon No.	Change in weight	Survival period	Results
Pen 47:			*Per cent*	*Days*	
Cooked White Leghorn eggs	15	225	−24.4	22	Polyneuritis.
		226	−17.3	19	Do.
Autoclaved rice	85	227	−29.7	46	Died.
		228	−14.1	15	Polyneuritis
Average			−21.4	26	
Pen 48:					
Cooked White Leghorn eggs	30	229	−15.6	29	Polyneuritis.
		230	−34.8	56	Emaciated at end of test.
Autoclaved rice	70	231	−10.3	29	Polyneuritis.
		232	−15.9	46	Do.
Average			−19.2	40	

DISCUSSION OF RESULTS

POULTRY FLESH

The relatively low antineuritic value that was found for the flesh of the frying chickens is surprising in view of the fact that the birds were grown on free range with an abundant supply of green feed, and in addition were fed mixed grains and mash that undoubtedly contained an ample supply of vitamin B.

The flesh of the hens was even more deficient in vitamin B, although they also were fed grain and mash that contained an ample supply of the vitamin, and in addition received considerable green feed, but not nearly so much as the young chickens. The slightly higher antineuritic value of the young chickens is probably due to the greater abundance of green feed in their diet. Apparently neither the young chickens nor the hens had the ability to store any considerable quantity of vitamin B in their muscle tissue.

There seem to have been no significant differences in the vitamin B content of the flesh of the three breeds of chickens. This applies both to the frying chickens and to the hens.

The turkey flesh had a rather low antineuritic value, similar to that of the frying chickens, while the flesh of the guinea fowl had a somewhat higher value. The flesh of the ducks had a considerably higher antineuritic value than that of any of the other fowl tested.

Since no information is available regarding the feeding of the turkeys, ducks, and guinea fowl, it can not be stated whether the higher antineuritic value of the duck and guinea-fowl flesh, as compared with that from the chickens and turkeys, may have been due to a difference in the vitamin B content of the rations of the birds or not. It is very unlikely, however, that the diet either of the ducks or the

guinea fowl was any richer in vitamin B than was that of the frying chickens. The facts available suggest that perhaps the ducks and the guinea fowl had greater capacity to store vitamin B in their muscle tissue than had the chickens. More evidence is necessary, however, before a positive conclusion can be drawn.

The hens' gizzards had a very low antineuritic value, but the hens' livers had a fairly high value, higher than that of any of the samples of poultry flesh. Twenty per cent of the dried hens' liver in a ration with autoclaved rice fully protected a pen of 3 pigeons against both polyneuritis and loss in weight during a period of 56 days. The hens' liver had a somewhat lower antineuritic value, however, than the liver of the ox, sheep, or hog, as previously reported by one of the writers (*2*).

EGGS

The results of our experiments show no significant differences in the vitamin B content of the eggs from the three breeds of chickens. The rather low antineuritic values that were obtained are somewhat surprising in view of the statements in the literature concerning the vitamin B content of eggs (*1*, *4*, p. *12*, *6*, p. *86*). A careful perusal of the article by Cooper (*1*) indicates, however, that his experimental data, if judged by the standards employed by the writers, do not show a high antineuritic value for eggs, but, rather, a relatively low one. For example, Cooper found that 10 grams of raw, undried egg yolk daily in the ration of each of 2 pigeons protected them against polyneuritis for 55 days, but that they had lost 3 and 7.5 per cent in weight, respectively. This quantity of egg yolk corresponds to 7 grams of dried whole egg, and would amount to 46.6 per cent of the ration fed daily to a 300-gram pigeon in our experiments.

SUMMARY

The investigations reported in this paper are not sufficiently comprehensive to warrant any final conclusion as to the vitamin B content of poultry flesh and eggs as found on the markets in this country, and the results are therefore offered simply as a contribution to our knowledge of the subject. It is realized that additional information concerning the vitamin B content of this class of products is much to be desired.

The results of the vitamin B studies with poultry flesh and eggs may be summarized as follows:

1. The flesh from the hens was relatively deficient in the antineuritic vitamin, while the flesh from the growing chickens had a slightly higher value.
2. The turkey flesh had a rather low antineuritic value.
3. The flesh from guinea fowl contained a fair supply of the antineuritic vitamin.
4. The duck flesh was richer in the antineuritic vitamin than that from any of the other fowls.
5. The hens' livers had the highest antineuritic value of any of the products tested, while the gizzards had a very low value.
6. The hens' eggs tested had a rather low antineuritic value.

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DISSEMINATION OF THE STEM AND BULB INFESTING NEMATODE, TYLENCHUS DIPSACI, IN THE SEEDS OF CERTAIN COMPOSITES[1]

By G. H. GODFREY,

Pathologist, Office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry, United States Department of Agriculture

The investigations recounted in this paper were carried on as a result of the finding of the widespread occurrence of the stem-nematode-infested false dandelion, *Hypochaeris radicata*, in the Pacific Coast States, as reported by Godfrey and McKay (*2*).[2] My subsequent discovery of the same nematode in the true dandelion, *Taraxacum officinale*, over a wide area in northeastern United States in July and September, 1923, made the problem of the manner of dissemination the more interesting.

REVIEW OF LITERATURE

A study of the literature has shown that both of these hosts are more or less abundantly infested by nematodes in Europe,[3] as indicated by their frequent mention by writers on plant galls. In 1885 Trail (*19, p. 211*) listed *Hypochaeris radicata* as subject to a gall caused by *Tylenchus sp.* He reported observing it first in Scotland, in 1882. This seems to be the earliest authentic report. In 1886 Liebel (*6, p. 547*, No. 124) listed it as subject to a "Helminthocecidium" which he described thus:

> Blattparenchym gallen: grünlichgelbe längliche Auftreibung der Blattmittelrippe, seltener ründliche bis längliche Auftreibung der Spreite. Die Aelchen darin in Anzahl.

Houard (*3, p. 1035*, No. 6040) in a comprehensive list of plant galls of Europe in 1909, listed this plant as having galls produced by "Anguillulide," Massalongo (*9, p. 8*, No. 7) in 1915 listed it as subject to a "Helminthocecidium" in Italy, described the symptoms, and illustrated with drawings typical affected leaves and stems, identical in appearance with the disease produced in this country by *Tylenchus dipsaci* (Kühn) Bast. Thus this plant is reported all the way from Scotland to Italy as subject to galls produced by nematodes, it seems safe to assume by *T. dipsaci*.

The true dandelion, *Taraxacum officinale*, was mentioned by Thomas in 1885 (*15*) as subject to a "Helminthocecidium," and more completely described the next year (*16, p. 304*, No. 49). The causal organism was referred to as *Tylenchus sp.* in a still later paper (*17*). It was found, in this instance, in "Grösster Menge auf den Wiesen um Cogne, Gimilian und Lillian, Piemont, bei 1,500 to 1,800 m. Meereshöhe." Liebel (*6, p. 573*, No. 288), in 1886, reported a "Helminthocecidium" on this host at Bolchen, Lorraine. Rübsaamen reported it in 1890 (*13, p. 53*, No. 207) in "Die Gallmücken und Galle des Siegerlandes." Houard (*3, p. 1042*, No. 6037) lists it for northern, central, and southern Europe as a *Tylenchus* gall. With *Taraxacum* again, though the specific parasite is not named, *Tylenchus dipsaci* is strongly indicated in every case.

[1] Received for publication Mar. 20, 1924.

[2] Reference is made by number (italic) to "Literature cited," p. 478.

[3] I gratefully acknowledge my indebtedness to Dr. G. Steiner, Office of Crop Technology, Bureau of Plant Industry, for his help in finding the pertinent European literature.

European writers report various other composites as subject to nematode galls, most of which, judging from the descriptions given (except the root galls) are probably due to *Tylenchus dipsaci*. These are tabulated herewith:

TABLE I.—*Composite plants subject to Nematode galls*

Host plant	Nematode as listed	Date	Authority
Antennaria dioica (L.) Gaertn	Anguillulidæ	1909	Houard (*5*).
Atractylis gummifera L	do	1912	Do.
Carduus defloratus L	Tylenchus sp	1896	Thomas (*18*).
Carlina corymbosa L	do	1909	Houard (*5*).
Cichorium intybus L	Anguillulidæ	1902	Geisenheyner (*1*).
Cirsium oleraceum (L) Scop	do	1896	Thomas (*18*).
Cirsium arvense (L) Scop	do	1902	Geisenheyner (*1*).
Cirsium bulbosum (Lam.) DC	do	1902	Do.
Crepis foetida L	Tylenchus devastatrix	1912	Houard (*5*).
Crepis leontodontodes All	Tylenchus sp	1905	Trotter (*20*).
Crepis taraxacifolia Thuill	Tylenchus devastatrix	1906	Maige (*8*).
Cynara cardunculus L	Tylenchus dipsaci	1912	Stefani Perez (*14*).
Hieracium auricula L	do	1903	Lagerheim (see Houard (*5*)).
Hieracium pilosella L	do	1883	Trail (*19*).
		1885	Liebel (*6*) and several others.
Leontodon hastilis L	Anguillulidæ	1885	Löw Fr. (*7*).
Leontodon hispidus L	Tylenchus sp	1907	Mariani (see Houard (*5*)).
		1896	Do.
		1901	Kieffer (*4*).
Leontodon incanus Schrank	Anguillulidæ	1885	Löw, F. (*7*).
Leontodon pyrenaicus Gouan	Tylenchus sp	1903	Lagerheim (see Houard (*5*)).

In only one of these cases, that of *Crepis taraxacifolia*, reported by Maige (*8*), was mention made of transmission of the nematode by seed. He described a condition of the flower head (capitule) very similar to that which occurs with the composites reported upon in this paper. He illustrated this condition with drawings, and treated of dissemination by the seed as follows:

Les capitules attaqués portant des fruits d'apparence normale, bien que remplis de larves enkystées, ces fruits peuvent grâce a leurs aigrettes, être transportés par le vent à de grandes distances et constituent ainsi pour le *Tylenchus devastatrix* un moyen de propagation des plus favorables.

The original paper on the stem nematode by Kühn (*5*) dealt with the organism in *Dipsacus fullonum* in the Dipsaceae, a family closely allied to the Compositae. Kühn wrote in this connection:

Diese Krankheit ist characterisirt durch ein allmäliges Missfarbigwerden und Vertrocknen der Blütenköpfe; Der Pappus des gesunden Samens ist gestielt, bei den kranken Körnern ist er fast doppelt so gross und sitzend. Die kranken Körner sind nicht vollständig mit Auguillulen ausgefüllt, vielmehr findet sich in denselben noch der verkümmerte Samenkern, während die ersteren zu weisslichen Häufchen vereinigt in dem Gewebe der abnorm verdickten Samenschale, namentlich am Grunde derselben vorhanden sind.

Thus he established the presence of the nematodes within the seed head and seed of *Dipsacus fullonum*.

DISTRIBUTION OF NEMATODE-INFESTED COMPOSITES IN AMERICA

HYPOCHAERIS RADICATA

As stated in the paper by Godfrey and McKay (*2*), the stem nematode occurs along the west coast of America all the way from Tacoma, Wash., to San Francisco, Calif., in *Hypochaeris radicata*. This plant is reported to have been introduced into that region. In this regard Piper and Beattie (*11*) stated in their Flora of the Northwest Coast: "A very troublesome weed in lawns and pastures; introduced from Europe." Nelson (*10*) listed it as a possible introduction with ballast dirt. Mr. M. W. Gorman, botanist, now curator of the Portland Historical Society, at the Forestry Building, Portland, Oreg., who is also familiar

with ballast flora, considers this a very great probability. He is familiar with the early appearance of the plant in the Northwest, and with its very rapid spread and increase until now it is one of the most common and troublesome of lawn and meadow weeds. He referred me to Fort Nisqually, near Olympia, Wash., as the site of an early ballast dump, and the very possible point of introduction of the weed. True enough, in 1923 I found *Hypochaeris* in that vicinity in unusually great abundance as a roadside, lawn, and garden weed. Early settlers in that region stated to me that they knew when it first appeared, approximately 50 years ago.

The interesting observation was made as well, that the parasitic nematode *Tylenchus dipsaci* was observed to be very abundant in that region, possibly even more so than where first observed in western Oregon, and certainly more abundant than in its southern range, in western California. It would appear to be very plausible to suppose that the parasite was introduced along with the host plant, and that the parasite as well as the host plant have become simultaneously widespread.

CREPIS VIRENS

While studying the flora associated with diseased *Hypochaeris*, I found a few typically affected plants of *Crepis virens*, first at Eureka, Calif., and later at Seaside, Oreg. They were by no means as abundant as affected *Hypochaeris radicata*, and merit attention only in the fact that they constitute a new host record for the organism.

TARAXACUM OFFICINALE

Stem-nematode-infested dandelions, *Taraxacum officinale*, were first encountered at Williamson, in Wayne County, N. Y., in July, 1923. Subsequently they were found occasionally all the way between Ithaca and Niagara Falls, and across the Niagara River, in the Province of Ontario, Canada. Plant disease survey forces in the State eventually reported the disease to be present in 14 counties in western New York. In September I found it among dandelions growing in a low meadow in Arnold Arboretum, in Boston, Mass.

With the true dandelion, therefore, as with the false dandelion in the West, considerable distribution of the parasite has taken place.

RELATION OF THE NEMATODE TO THE SEED

When first observations were made on nematode-diseased *Hypochaeris*, the plant was not flowering, consequently the disease was to be found only in the leaves. (*2*, Pl. 2). Later summer observations, however, disclosed the presence of swellings in the flower pedicels. The abundant occurrence of stem swellings due to an insect, *Aulax hypochaeridis* (Pl. 1, A) were at first confusing. Characteristic nematode swellings became evident, however, usually in the pedicel at the base of the flower head. These were irregular, resulting sometimes in considerable distortion, and were distinctly soft, rather than hard as were the insect galls. Typical blossoms in this condition, compared with the normal, are shown in Plate 1, B and C. As stated previously, the swellings pictured by Massalongo (*9*) are identical in appearance with these.

Such affected stems of *Hypochaeris* when cut longitudinally showed brownish discoloration in the receptacle, and for a short distance below, in the pith of the stem. This condition is illustrated in Plate 1, D. The discolored tissue was found to contain an abundance of living, active *Tylenchus* in all stages of development.

Flowers in various stages of development were studied. By microscopic examination it was seen that some of the very young seed were discolored at their

point of attachment with the receptacle. These were found to contain nematodes. The eelworms could readily be seen with the binocular coiled up in the interior, through the semitransparent achene wall, as shown by Plate 2, A. Seeds in more advanced stages of development were found, upon dissection, to contain living nemas. One showed a nema extending from the base. Another (Pl. 2, B) showed one at the upper extremity, at the base of the pappus stalk. Some of the seeds were killed by the invasion, as shown by their completely collapsed condition. In some of the invaded seeds, however, such injury did not occur, for the seed was intact, since the eelworms were present only between the achene wall and the testa of the seed.

Experimental plantings of seed from diseased flower heads produced a reduced stand of seedlings, among which were several typically diseased plants. Swellings appeared first in the petioles of the primary leaves, and subsequently in one or two of the permanent leaves. Plate 2, C, shows one of the affected seedlings with characteristic swelling in the midrib of the first secondary leaf. Examination of such a plant three days after infection was first evident disclosed larvae of *Tylenchus dipsaci* not yet quite sexually mature. In all invaded seed observed, the pappus was apparently normal and the seed capable of being transported by the wind. Plate 2, D, shows several mature seed of *Hypochaeris radicata*. Some of this same lot were later shown to contain living nemas.

In the true dandelion (*Taraxacum officinale*) exactly the same conditions existed. The leaf symptoms are identical with those previously described for *Hypochaeris radicata*. Plate 3, C, shows typical leaf swellings. Plate 3, A, shows one of many nematode-infested heads found, this one sectioned to show the discolored receptacle and seed bases. More than 50 per cent of the seed in this particular head were invaded by nemas. One of the seeds with its pappus is pictured in Plate 3, B. The seed is undamaged in spite of the fact that a nematode was present beneath the outer seed coat.

A study of growing plants made it evident how primary invasion of the seed head takes place. Both *Taraxacum* and *Hypochaeris* grow as a "rosette" on the ground, with flat leaves radiating from a common center. The outer ends of the leaves often are higher than the inner, thus permitting dew and rain to flow in toward the center, carrying with them free nemas that have migrated out of infested spots in the leaves. *Tylenchus dipsaci* was thus observed many times in the young, actively growing central region of the plants, some of them free from the host tissues, others within the young, highly susceptible parts. Without doubt much of the leaf infection takes place when the leaves are young. It is likewise in this region that the flower heads form and develop. Ready infestation of the flower head can thus take place, and, indeed, many young heads were observed that were thus infested. Plate 3, D, a photograph of a dandelion plant sectioned longitudinally, shows two flower heads in different stages of development, and their obviously favorable location, when young, for infection by nemas. The well-known rapid growth of the pedicel after the flower is fully developed is a factor which favors the dissemination of the invading parasites, as well as of the seed, by the agency of the wind.

It is evident that dissemination of the nemas by the seed is easily accomplished, and under natural conditions it undoubtedly takes place to a large extent. If the seed has been killed, the eelworms released may still infest plants that are already established. If the infested seed is alive then a new colony is established at once, with the host plant immediately available. Thus is explained the distribution of the nematode parasite to an extent that is practically coequal in range with that of its host, the false dandelion, in the Pacific Coast States, and the probably widening circle of infestation in the true dandelion in the Northeast.

SEEDS OF OTHER PLANTS LIKEWISE NEMATODE CARRIERS

The dissemination of parasitic stem nematodes undoubtedly takes place by means of the seed of other composites and allied plants in a similar manner. Reference has already been made to the observations of Maige (*8*) in *Crepis taraxacifolia*. Geisenheyner (*1*) described a gall due to "Anguillulides" in *Cirsium bulbusom* in which the swelling is situated at the base of the flower head. (*3*, No. 5915, p. 1016), as it is in *Hypochaeris* and *Taraxacum* in America. A like condition exists with *Leontodon incanus*, in which the "Tige est epaissie et tordue, au-dessous de l'inflorescence, sur un longeur de 20 mm. et plus," etc., according to Houard (*3*, No. 6048, p. 1036). Likewise, in *Hieracium pilosella* "Capitule gonflé et contourné demeurant fermé, porté sur une hampe florale renflée." (Houard, *3*, No. 1698, p. 1057). In all probability the seeds of all these plants are penetrated by the nemas, without injuring their capacity of being carried by the wind.

In *Dipsacus fullonum*, a member of the family Dipsaceae, which is very close to the Compositae, the same manner of dissemination undoubtedly occurs, as already cited (*5*). Ritzema Bos (*12*) mentioned infestation in onion seedlings (*Allium cepa*) in the earliest stages of their development. A large part of this was due to the fact that penetration had taken place from infested soil shortly after the appearance of the cotyledon through the seed coat. In addition, however, he found *Tylenchus dipsaci* in the blossoms of mature plants, and in one case 3 per cent of the seeds were infested. In many other plants whose seeds are not windblown it is possible that the nemas enter the seed and are carried with them.

Dissemination of the plant parasitic nematodes on the surface of seed undoubtedly takes place to a large extent as well. This will be treated at length in another paper in connection with experimental work on the clover and alfalfa stem nematode.

SIGNIFICANCE OF WIND DISSEMINATION OF THE STEM NEMATODE

It is too early to make any estimate as to whether or not this great spread of the stem nematode in the composites may be of any economic significance. Indeed, any disease that even suggests the possible lessening of the spread of either the false or the true dandelion might be looked upon as a blessing rather than otherwise, except possibly in connection with the few fields of cultivated *Taraxacum* grown for food. Thus far the indications are that the nemas infesting the composites are specialized physiological races not capable of infesting others of the known economic host plants. There are indications of gradual adaptation to new host plants, however. Further investigations are being made in this connection.

SUMMARY

(1) The leaf and stem infesting nematode, *Tylenchus dipsaci* Kühn, has been found to be abundant on the false dandelion, *Hypochaeris radicata*, along the Pacific coast, from Tacoma, Wash., to San Francisco, Calif. It occurs as well in the true dandelion, *Taraxacum officinale*, in Western New York, the Province of Ontario, Canada, and at Boston, Mass. According to the literature, it occurs abundantly on these and other composites in Europe.

(2) In addition to producing swellings and distortions of the leaves, the nemas penetrate the developing flower head and produce more or less distortion in that region. Furthermore, in the case of the false and true dandelion they were observed to have actually penetrated into the interior of the seed.

(3) This accounts definitely for their wide distribution on these hosts, for the wind carries the nematode-infested equally well with the nematode-free seed.

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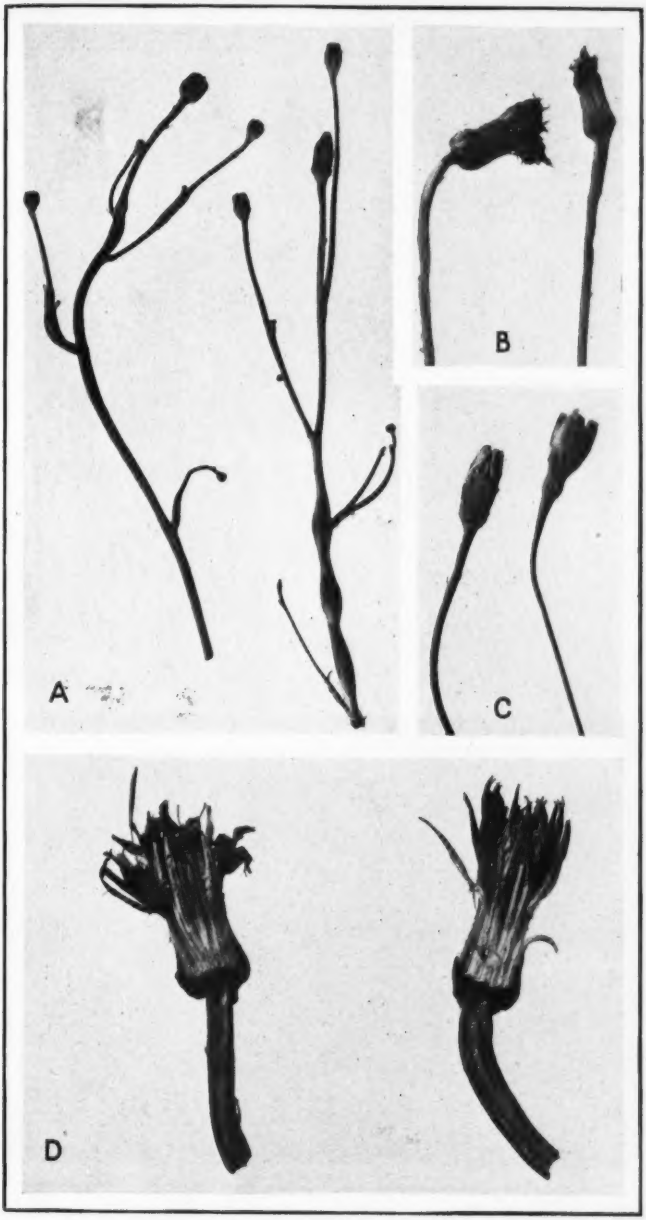
PLATE 1

A.—Stems of false dandelion, *Hypochaeris radicata*, showing galls produced by the insect *Aulax hypochaeridis* Kieff. These are shown to distinguish them from the galls caused by the stem nematode, *Tylenchus dipsaci*.

B.—Immature flower heads of false dandelion showing stem nematode swellings at the base of the flower head.

C.—Normal flower heads of *H. radicata;* compare with B.

D.—Sections through nematode-infested heads of *H. radicata*. Note the discolored receptacle, which contains hundreds of nematodes.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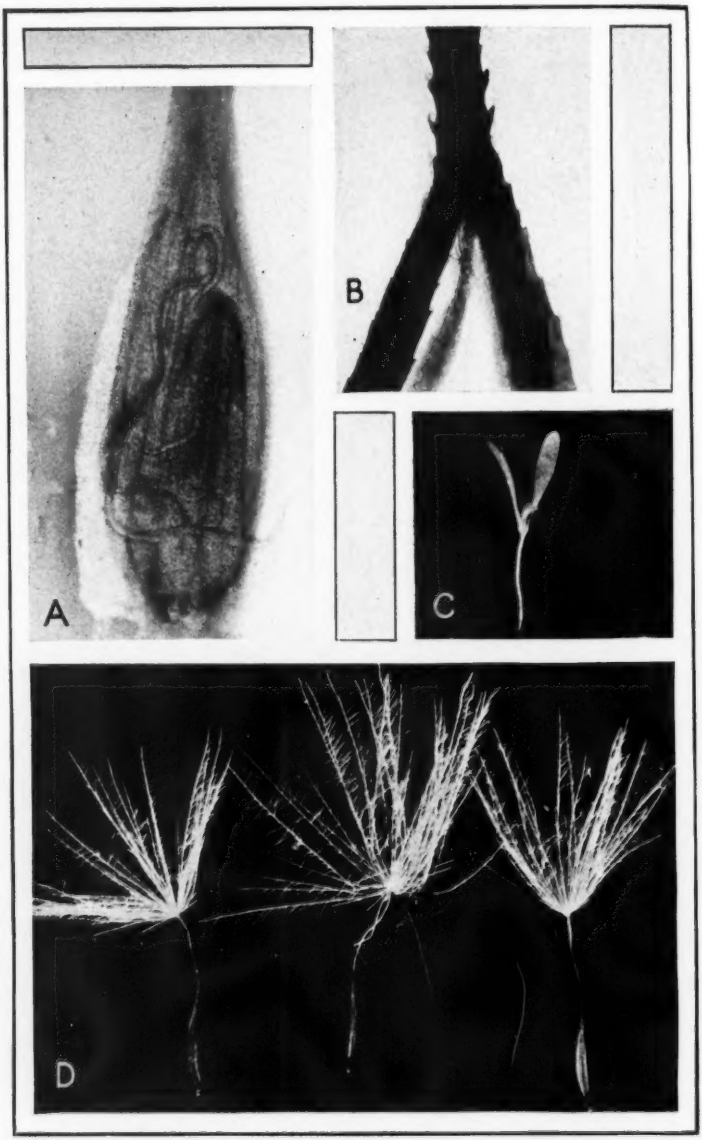
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PLATE 2

A.—Photograph of immature seed of *Hypochaeris radicata*, showing nemas coiled inside the seed; taken by transmitted light.

B.—Apical end of a mature seed, showing nematodes within the seed.

C.—Small seedling of *Hypochaeris radicata* showing typical *Tylenchus* swelling in the midrib of the first permanent leaf. This is one of several such plants that resulted from planting seed from a mature infested flower head into a flat of sterilized soil in the greenhouse.

D.—Three typical seed of *Hypochaeris radicata*, taken from an infested flower head. About half the seed from this same lot contained living nematodes.

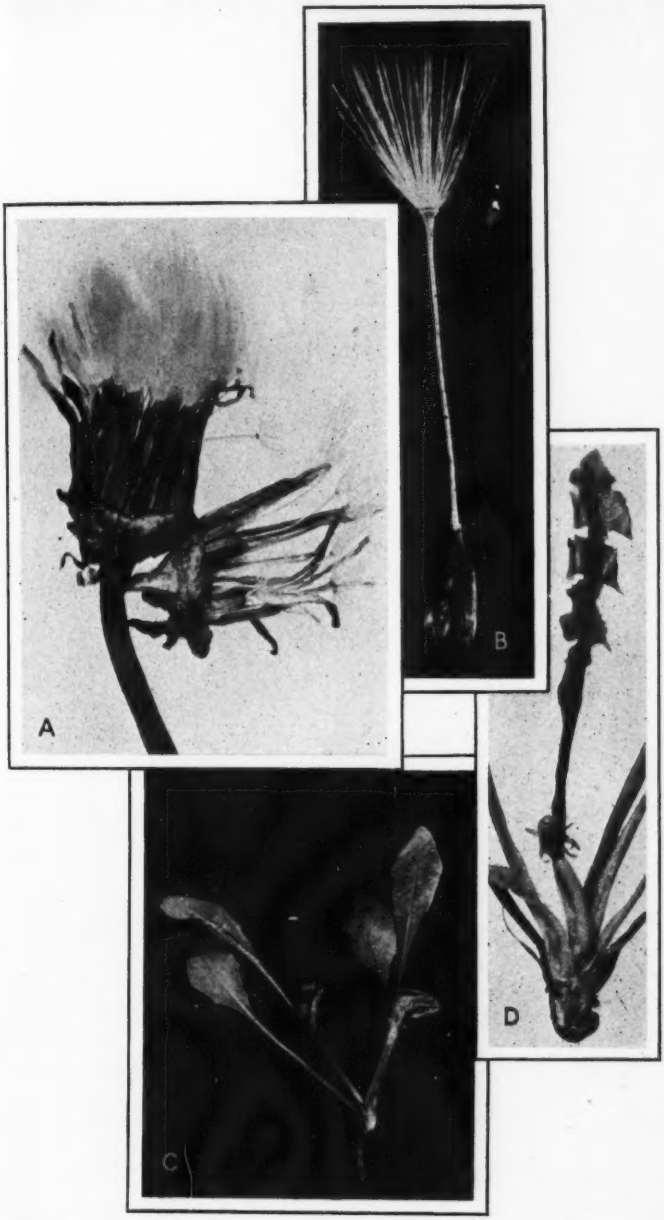
PLATE 3

A.—A flower head of true dandelion, *Taraxacum officinale*, broken open longitudinally to show the slightly discolored receptacle and seed bases. More than 50 per cent of these seeds contained living *Tylenchus dipsaci*.

B.—A single seed of *T. officinale*, from which two living Tylenchi were dissected. Note the seed proper, which was intact, and the normal pappus.

C.—A young plant of *Taraxacum officinale* with three leaves showing typical *Tylenchus* deformities.

D.—A dandelion plant sectioned longitudinally through the crown to show the developing flower heads. Note that when very small they are in the very heart of the plant, protected from ordinary mechanical injury, unquestionably, but ideally situated for infection by the stem nematode.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SOME MODIFICATIONS OF THE PICRIC ACID METHOD FOR SUGARS[1]

By J. J. WILLAMAN and F. R. DAVISON, *Division of Agricultural Biochemistry, Minnesota Agricultural Experiment Station*

INTRODUCTION

The writers recently had occasion to use the picric acid colorimetric method (commonly called the Benedict-Lewis method)[2] for determining the sugars in cornstalk juices.[3] Although it has been used mostly as a micro method for blood and urine analyses, it has been used to some extent as a macro method. (*3*,[4] *5*, *12*.) It proved to be more rapid than, and approximately as accurate as, a copper reduction method after certain modifications had been introduced to eliminate certain sources of error. The following is a description of the errors met with and the corresponding modifications.

METHOD

The basic procedure, the various items of which were made the subject of the present investigation, was taken from Rose (*16*) and is as follows:

One cubic centimeter of sugar solution of proper concentration is transferred to a long narrow test tube (so-called sugar tube, graduated to 10 cc.) containing 2 cc. of saturated picric acid and 1 cc. of 20 per cent sodium carbonate solution. The test tube is then immersed in boiling water for 20 to 30 minutes to effect reduction of the picrate to picramate. The solution is then made up to volume. The color present represents the reducing sugars and is compared to a standard in a colorimeter.

When sucrose is to be determined 1 cc. of sugar solution is mixed with 2 cc. of saturated picric acid in a sugar tube and heated in boiling water 10 minutes to effect hydrolysis. One cubic centimeter of 20 per cent sodium carbonate is then added and the tube heated in boiling water for 20 to 30 minutes to develop the color. This color represents the total sugars. The difference between the two sets represents the sucrose present.

All color measurements were made in a Kober colorimeter.

The various items for which modifications are suggested are the color standard, the effect of picric acid on glucose, the dilution of the unknown color, clarification, the calculation of results, and the color factors for various sugars.

THE COLOR STANDARDS

Several color standards have been suggested, but all of them have some disadvantageous feature. The picramate color does not match ferric acetate (*8*), potassium bichromate, or o-nitrophenolate (*5*). Dehn and Hartman (*5*) used the color produced by a standard glucose solution, while Lewis and Benedict (*10*) used pure picramic acid.

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[2] Thomas, W., and Dutcher, R. A. The application of the Benedict-Osterberg method to the quantitative estimation of carbohydrates in plant tissues. Paper presented at convention of Amer. Chem. Soc., Milwaukee, Wis., September, 1923. (Not published.)

[3] Willaman, J. J., Burr, G. O., and Davison, F. R. Cornstalk sirup investigations. In press.

[4] Reference is made by number (italic) to "Literature cited," pp. 487–488.

At first it was thought that a standard glucose solution in saturated picric acid might be a convenient source of color, since a standard tube could be prepared each time a series of analyses is run. It was found, however, that such a solution gradually increases in color-producing value, being about 115 per cent of its original value at the end of a year. The change is rather slow, however, and the solution may be used for about a week without any appreciable change being noticed. Solutions of pure picramic acid, or of sodium picramate, match the sugar colors exactly, but in the writers' experience they fade too rapidly to be satisfactory. It was thought that the change might be hastened to completion by treating with heat or with intense light or with both. But instead of fading, the color became more intense during the treatment, and then faded again, so this method proved useless. The usual method is to make a standard glucose solution each time a set of analyses is to be run. This is time-consuming but accurate, and is possibly the best procedure available at present, especially where analyses are not run daily.

Another procedure that was tried was to make the color in bulk from sugar, and then store in amber bottles. Without giving the data in detail, it is sufficient to say that the colors from both sucrose and glucose, made in quantities of 500 cc., and stored in both clear and in amber bottles, faded rapidly. After 30 days the fading was much slower, but it was still too marked even after 100 days to warrant using the material as a standard.

From the above experiences, the writers recommend as a standard an 0.08 per cent glucose solution in saturated picric acid, making a new solution each week. A reduction in sugar tubes is made with each set of analyses run, using 1 cc. of sugar, 1 cc. of water, 1 cc. of saturated picric acid, and 1 cc. of 20 per cent sodium carbonate solution. This is the equivalent of using 1 cc. of unknown sugar solution and 2 cc. of picric acid. This is the most convenient standard where daily analyses are run. Where the analyses are intermittent, it is simpler to make an 0.08 per cent glucose solution in water, and make reductions of it in the usual way.

EFFECT OF PICRIC ACID ON GLUCOSE AND FRUCTOSE

It was mentioned above that glucose, on standing in picric acid at room temperature, gradually increases its chromogenic value. It was also stated that when sucrose is to be determined by the present method the solution of sugar is first heated for 10 minutes with the picric acid alone, for inversion, and then heated again with sodium carbonate, for reduction. (Rose (*16*) found 10 minutes was sufficient for inversion, and this has been corroborated by the writers.) It was noticed that sucrose always gave more than its theoretical color value. These facts suggested that either the heating in the presence of picric acid has some effect on the glucose and fructose, or the fructose constituent has a greater chromogenic value than the glucose. The latter alternative was proved not to be the case, as will be mentioned below.

It was then decided to investigate the heat effect. Okey (*13*) found that both glucose and fructose have enhanced color values when heated with picric acid, and she abandoned the attempt to use picric acid as a hydrolyst for inulin. A standard glucose solution was treated both ways: that is, the color developed both with and without the 10-minute heating with picric acid. These two treatments duplicate the procedure for total sugars and for reducing sugars, respectively. The results are shown in Table I. It is apparent that glucose gives a more intense color when subjected to a preliminary heating with picric acid. Heating for 10 minutes causes a maximum development of color. In further trials this color was found to be constant regardless of the ratio of reducing sugars to sucrose

present. Evidently the sucrose is inverted in a short time and the invert sugar produced is exposed to the picric acid for the greater part of the 10-minute period. Fructose was not tried alone, but sucrose gave quantitatively the same effect as glucose alone. Because of this, and because Okey got similar results, it was assumed that both glucose and fructose were affected in the same way by the picric acid. The ratio of the color values with and without the heating in presence of picric acid, or in other words the "total" to "reducing sugar" values, was determined, and found to be 1.045.

This difference in color development may be dealt with in two different ways in making analyses by this method: Either two standards may be used, one for "total" and one for "reducing" sugars, or one standard can be used for both and a factor applied. The latter method was decided upon and the factor 1.045 has been used throughout the present work.

TABLE I.–*Effect of heating on an 0.08 per cent glucose solution in picric acid before heating with sodium carbonate—comparison made with a standard 0.08 per cent glucose set at 30 mm.*

Time of heating, minutes	10	15	20	25	30
Colorimeter readings:					
Series I	28.7				
Series II	28.6				
Series III	28.8	28.8	28.4	27.9	28.6

EFFECT OF DILUTING THE PICRAMATE COLOR

In analyzing an unknown material, a color too intense for reading in the colorimeter may be obtained when the solution is diluted in the conventional manner to 10 c.c. Therefore it was desired to know whether the colored solution could be diluted to other volumes without destroying the proportionality of intensity. Determinations were run on 0.64, 0.32, and 0.16 per cent glucose and the resulting colors made to 80, 40, and 20 cc. respectively. These were then compared with an 0.08 per cent glucose made to 10 cc. The results are shown in Table II. It is apparent that either the high ratio of sugar to picric acid, or the dilution itself, disturbs the proportionality rather seriously. Hence dilution cannot be used to remedy a color that is too strong for comparison, although this has often been recommended (*2*, *11*, *12e*). Dehn (*4*) lists this dilution effect among his fallacies of colorimetry.

CLARIFICATION

The choice of a clarifying agent is of primary importance in any sugar method. In trying to choose the best one for the present method some surprising results were obtained, which tend to cast doubt on the necessity of clarification in the case of many materials.

Benedict (*1*) clarified blood from proteins with picric acid. Folin and Wu (*6*) used a tungstic acid preparation for clarification. Höst and Hatlehol (*7*) made a comparative study of blood sugar results and found the Folin-Wu method gave good results both on tungstate and picric-picrate filtrates; while the Benedict method gave high results with picric-picrate filtrates.

TABLE II.—*Effect of dilution on the color value of glucose solutions*

Glucose solution	Final volume	Colorimeter reading	Recovery
Per cent	*Centimeter*	*Millimeter*	*Per cent*
0.08	10.0	30.0	100
0.16	20.0	28.5	105
0.32	40.0	27.7	108
0.64	80.0	27.4	110

TABLE III.—*Comparison of clarification methods*

Material	Sucrose		Reducing sugar		Total sugar	
	Not clarified	Clarified	Not clarified	Clarified	Not clarified	Clarified
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
LEAD ACETATE						
Corn-stalk juice	5.50	5.53	3.15	3.28	8.65	8.81
Do	10.23	10.06	2.93	2.97	13.16	13.03
Do	5.14	5.11	2.96	3.04	8.10	8.14
Do	8.82	8.92	3.23	3.02	12.15	11.94
Do	6.62	6.70	2.93	2.97	9.55	9.67
Do	11.42	11.26	3.03	3.04	14.45	14.30
Apple juice			8.40	8.46		
Grape juice			17.80	17.66		
ALCOHOL						
Corn-stalk juice	5.43	5.42	3.36	3.37	8.79	8.76
Do	4.54	4.56	3.20	2.98	7.74	7.54
SODIUM TUNGSTATE						
Corn-stalk syrup			14.50	14.56		
Sorghum syrup			11.10	11.30		
Do			18.10	18.10		
Diastophore			14.50	14.40		
PICRIC ACID						
Sorghum syrup	37.26	39.33	34.92	32.04	72.18	71.37
Do	24.25	27.67	35.64	33.12	59.89	60.79

Table III shows the results obtained by various methods of clarification. When lead acetate was used deleading was accomplished with potassium oxalate.

Alcohol clarification of corn juice was obtained by heating 400 cc. of juice with 600 cc. of 95 per cent alcohol for 20 minutes in a water bath. The alcoholic filtrate was diluted 25 times with water and 1 cc. was used for a sample, without removing the alcohol.

Rumsey's directions (17) for clarification with sodium tungstate were followed, an acidity of approximately P_H 2 being obtained with sulphuric acid. The filtrate was diluted 100 times and used for analysis without the removal of the excess tungstate. The "diastophore" is a malt extract preparation.

Picric acid clarification was obtained by saturating the sugar solution with crystals, allowing it to stand for a few minutes, filtering, and analyzing the filtrate immediately, so as to preclude the possibility of inversion of sucrose.

The results show in general that clarification is unnecessary with the picrate method with the materials so far analyzed. Undoubtedly the picric acid clarification could be effective only when proteins are present, and the latter are probably absent in the syrups analyzed. Therefore the above results do not necessarily preclude the desirability of using it in the case of other materials, as, for example, the vegetables analyzed by Myers and Croll (*12*).

Preparations which contain chlorophyll, and which have been preserved in alcohol, have to be clarified with lead after dilution, since the chlorophyll precipitates and must be removed. The writers suggest that, when a number of samples of a given material are to be analyzed with the present method, lead clarification be used on a few samples, and then, if no effect is noticed, that no clarification at all be used.

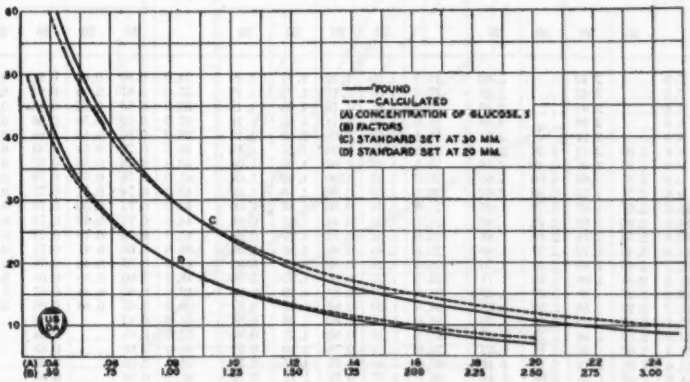

FIG. 1.—Color values of a series of glucose solutions from 0.02 per cent to 0.24 per cent, using the 0.08 per cent solution as a standard. From this graph the factors in Table IV were obtained

CALCULATION OF RESULTS

It is generally assumed, in using a colorimeter, that the height of the column of liquid required to produce a given intensity is inversely proportional to the concentration of the colored substance, when there is not too great a difference in the intensity of the two solutions. Dehn (*4*) has pointed out the fallacy of this. For example, the writers found that, if two solutions of sugars are measured, one just double the strength of the other, and the weaker placed at 30 mm., the stronger reads 13.8 instead of 15. Conversely, if the stronger is set at 30, the weaker reads 64 mm. instead of 60 mm. The stronger is always too strong, and the weaker too weak. In practice, this discrepancy is met by the use of standards which have about the same intensities as the unknowns have. But this involves a series of standards. Kober (*9*) has a correction formula for nephelometry that applies in colorimetry also, but it was thought simpler to establish a table of corrections rather than to apply the formula to each calculation. The picramate color was prepared from glucose solutions varying in concentration from 0.02 to 0.24 per cent, the feasible range for the colorimeter used. The procedure for total sugars was used; that is, the glucose was heated for 10 minutes with the picric acid alone, and then 30 minutes with sodium carbonate. The 0.08 per

cent glucose solution was used as a standard and set at 30 mm. and at 20 mm. The readings were then plotted and curves drawn. From the curves a table was constructed showing the factor by which the percentage strength of the standard used is multiplied in order to obtain the concentration of the unknown solution at any reading on the colorimeter. The columns for reducing sugars were obtained by multiplying the "total" factors by 1.045. Figure 1 contains the curves from which the factors in Table IV were obtained. The dotted line in the chart represents the theoretical ratios of direct proportionality.

TABLE IV.—*Factors for obtaining the "total" and "reducing" values of solutions for colorimeter readings from 7 to 60*

Colorimeter reading	Total sugar		Reducing sugar		Colorimeter reading	Total sugar		Reducing sugar		Colorimeter reading	Total sugar		Reducing sugar	
	Standard set at—		Standard set at—			Standard set at—		Standard set at—			Standard set at—		Standard set at—	
	30	20	30	20		30	20	30	20		30	20	30	20
7.0	.....	2.49	.....	2.60	16.5	1.69	1.19	1.77	1.24	34.0	0.89	0.60	0.93	0.63
7.3	.....	2.42	.....	2.53	17.0	1.65	1.16	1.73	1.21	35.0	0.87	0.58	0.91	0.61
7.6	.....	2.35	.....	2.46	17.5	1.61	1.13	1.68	1.18	36.0	0.84	0.57	0.88	0.60
8.0	.....	2.28	.....	2.38	18.0	1.56	1.11	1.63	1.16	37.0	0.82	0.56	0.86	0.59
8.3	.....	2.21	.....	2.31	18.5	1.53	1.08	1.60	1.13	38.0	0.80	0.55	0.84	0.57
8.6	3.09	2.14	3.23	2.24	19.0	1.49	1.05	1.56	1.10	39.0	0.79	0.54	0.83	0.56
9.0	2.97	2.07	3.10	2.16	19.5	1.46	1.03	1.53	1.08	40.0	0.78	0.53	0.82	0.55
9.3	2.87	2.00	3.00	2.09	20.0	1.43	1.00	1.49	1.04	41.0	0.76	0.52	0.79	0.54
9.6	2.77	1.93	2.89	2.02	20.5	1.40	0.98	1.46	1.02	42.0	0.74	0.51	0.77	0.53
10.0	2.67	1.87	2.79	1.95	21.0	1.38	0.96	1.44	1.00	43.0	0.73	0.50	0.76	0.52
10.3	2.60	1.82	2.72	1.90	21.5	1.36	0.94	1.42	0.98	44.0	0.71	0.49	0.74	0.51
10.6	2.53	1.78	2.64	1.86	22.0	1.33	0.92	1.39	0.96	45.0	0.70	0.48	0.73	0.50
11.0	2.46	1.72	2.57	1.80	22.5	1.30	0.90	1.36	0.94	46.0	0.68	0.47	0.71	0.49
11.3	2.40	1.68	2.51	1.76	23.0	1.28	0.88	1.34	0.92	47.0	0.67	0.46	0.70	0.48
11.6	2.34	1.64	2.44	1.71	23.5	1.25	0.86	1.31	0.90	48.0	0.66	0.45	0.69	0.47
12.0	2.27	1.60	2.37	1.67	24.0	1.23	0.84	1.29	0.88	49.0	0.64	0.44	0.67	0.46
12.3	2.22	1.56	2.32	1.63	24.5	1.20	0.83	1.25	0.87	50.0	0.63	0.43	0.66	0.45
12.6	2.17	1.52	2.27	1.59	25.0	1.18	0.82	1.23	0.86	51.0	0.62	.....	0.65	.....
13.0	2.12	1.48	2.22	1.55	25.5	1.16	0.80	1.21	0.84	52.0	0.61	.....	0.64	.....
13.3	2.07	1.45	2.16	1.52	26.0	1.13	0.78	1.19	0.82	53.0	0.60	.....	0.63	.....
13.6	2.02	1.42	2.11	1.48	27.0	1.10	0.76	1.15	0.79	54.0	0.59	.....	0.62	.....
14.0	1.97	1.38	2.06	1.44	28.0	1.07	0.73	1.12	0.76	55.0	0.58	.....	0.61	.....
14.3	1.93	1.35	2.02	1.41	29.0	1.03	0.70	1.08	0.73	56.0	0.57	.....	0.60	.....
14.6	1.89	1.32	1.97	1.38	30.0	1.00	0.68	1.04	0.71	57.0	0.56	.....	0.59	.....
15.0	1.85	1.29	1.93	1.35	31.0	0.97	0.66	1.01	0.69	58.0	0.55	.....	0.57	.....
15.5	1.79	1.25	1.87	1.31	32.0	0.94	0.64	0.98	0.67	59.0	0.54	.....	0.56	.....
16.0	1.73	1.22	1.81	1.27	33.0	0.92	0.62	0.96	0.65	60.0	0.53	.....	0.55	.....

The necessity for a special set of factors to be used when the standard is set at 20 mm. was brought out when four color preparations were compared to an 0.08 per cent glucose standard set at 10, 20, 40, and 50 mm. The results are plotted in Figure 2. The dotted line represents the theoretical values which should be obtained if strict proportionality existed, calculated from the lowest reading of the standard in each set.

COLOR FACTORS FOR VARIOUS SUGARS

Since all reducing sugars give picramic acid when acting on picric acid, these various sugars can be determined by the present method, provided no interfering substances, either sugars or nonsugars, be present. It was therefore thought desirable to determine the chromogenic value of certain of the commoner sugars. Dehn and Hartman (*5*) give several of these, but not in the form of usable factors. The sugars used by the writers were of the highest purity, and met the specifications of Pfanstiehl and Black (*14*) for the rare sugars. The colors produced were compared to the color from a standard glucose solution. The procedure for

"reducing" sugars was used; the effect of heating these various sugars with picric acid was not determined. The values given in Table V are for anhydrous sugars, and are based on glucose as unity. They are the ratios of the color intensity of glucose compared to the intensities of equal weights of the other sugars.

TABLE V.—*Color values of various sugars, compared with glucose as 1.000*

Sugar	Color value	Conversion factor	Sugar	Color value	Conversion factor
Glucose	1.000	1.000	Rhamnose	1.298	0.774
Fructose	1.000	1.000	Lactose	0.750	1.333
Maltose	0.770	1.298	Arabinose	1.000	1.000
Mannose	1.000	1.000	Xylose	1.071	0.934
Galactose	0.883	1.132			

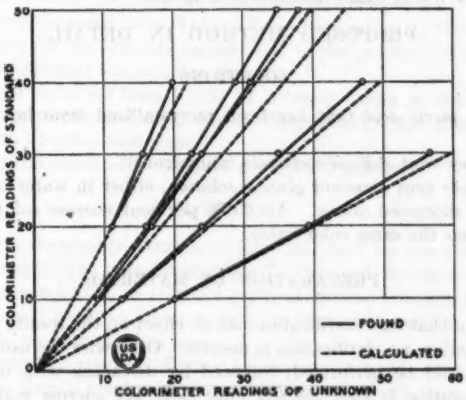

FIG. 2.—Curves showing the differences in color value obtained when the standard is set at 10, 20, 30, 40, and 50 mm.

In using this method on solutions of sugars other than those having a color value of 1.000, either a standard may be made from the pure sugar involved, or the ordinary glucose standard may be used; and, after calculating the sugar content in the usual manner according to the suggestions below, the number obtained is multiplied by the conversion factor given in the table for the particular sugar involved.

MINOR PRECAUTIONS

Rhode and Sweeney (*15*) and Benedict (*1*) have emphasized the importance of the purity of the picric acid used in this method, not only from the standpoint of its color-producing properties, but from that of its precipitating power towards proteins. The writers tried the various methods of purification of picric acid that have been suggested, and found practically no difference. Therefore simple recrystallization from hot water acidified with 15 cc. of concentrated hydrochloric acid per liter is recommended.

Benedict and Osterberg (*2*) pointed out the necessity of a proper proportion of picric acid to sugar. The writers found that varying the proportions does affect the intensity of color produced. They therefore emphasize the necessity of using

exactly 1 cc. of unknown sugar solution, 2 cc. of saturated picric acid, and 1 cc. of 20 per cent sodium carbonate.

During the 30 minutes of heating in a water bath, evaporation of water from the sugar tubes may be prevented (1) by loosely inserting corks covered with tinfoil in the tops of the tubes; and (2) by keeping the level of water in the bath approximately at the same level as the solutions in the sugar tubes. A wire rack fitting into a basin is a very convenient holder for the tubes.

Thus it will be seen that the conditions involved in determining sugar by this method are rather empirical. The writers believe that extreme empiricism is the only feasible basis for any colorimetric method. A given procedure and set of conditions must be decided upon, and then rigidly adhered to, whether they give maximum color intensities or not. The unknown color will be exactly comparable to the known, since they were both produced under exactly the same conditions. From this standpoint the most significant points in the present method are the effect of heat and picric acid on glucose, the use of the table of factors, and the use of exact amounts of reagents.

PROPOSED METHOD IN DETAIL

SOLUTIONS

1. *Saturated picric acid* that has been recrystallized from hot dilute hydrochloric acid.

2. Twenty per cent *sodium carbonate* (anhydrous).

3. An 0.08 per cent *standard glucose solution*, either in water or in saturated picric acid, as discussed above. An 0.076 per cent sucrose solution is equally suitable, and has the same color value.

PREPARATION OF MATERIAL

If it is known that lead clarification has no effect on the results with the sugar solution in question, no clarification is needed. Otherwise the usual lead acetate clarification should be performed, followed by deleading with disodium phosphate. The solution is then diluted until both the sucrose and the reducing sugars are between 0.02 and 0.24 per cent.

REDUCTION

1. *Reducing sugars.*—One cubic centimeter of the diluted sugar solution is pipetted into a sugar test tube, followed by 2 cc. of picric acid and 1 cc. of sodium carbonate. The solutions are thoroughly mixed and the tube lightly stoppered with a cork covered with tinfoil. The tubes are then immersed in boiling water for 20 to 30 minutes. They are then cooled and the contents diluted to the 10 cc. mark and shaken.

2. *Total sugars.*—One cubic centimeter of the diluted sugar solution and 2 cc. of picric acid are pipetted into a sugar test tube and immersed in boiling water for 10 minutes. Then 1 cc. of sodium carbonate solution is added, the mixture shaken, and the heating continued for 20 to 30 minutes. Cooling, mixing, and diluting are then conducted as stated above.

3. *Standard color.*—One cubic centimeter of the standard glucose or sucrose solution is treated the same as for *total sugars*.

COLOR MEASUREMENT

The zero point of the colorimeter is adjusted, using the standard color solution on both sides. The *reducing* and *total* colors are measured against the standard set at 30 mm. or at 20 mm.

CALCULATION

$$R = f_r \times \text{Std.}$$
$$T = f_t \times \text{Std.}$$
$$S = 0.95\,(T-R).$$
$$T' = R+S$$

Where

R = per cent of reducing sugars in the solutions analyzed.

S = per cent of sucrose in the solution analyzed.

T = per cent of total sugars (apparent) in the solution analyzed.

T' = per cent of total sugars (true) in the solution analyzed.

f_r = the factor obtained from Table IV, corresponding to the colorimeter reading for the *reducing* sugars, and to the position of the standard (30 or 20 mm.) for reducing sugars.

f_t = the factor obtained from Table IV, corresponding to the colorimeter reading for the *total* sugar and to the position of the standard (30 or 20 mm.) for the *total* sugar.

Std. = value of the standard in terms of per cent of glucose.

SUMMARY

1. A search for a reasonably permanent color standard for use with the picric acid method for sugars has been unsuccessful. The best standard is either an 0.08 per cent glucose solution, or an 0.076 per cent sucrose solution, in saturated picric acid, which will keep for about a week; or these same solutions in water, in which case they must be used at once.

2. Heating glucose in a solution of picric acid previous to reduction in a sodium carbonate solution gives a greater color value than without the treatment.

3. When the picramate color is diluted, the intensity of the color is not proportional to the dilution. Therefore the color is always diluted to exactly 10 cc.

4. Clarification of sugar solutions has proved to be unnecessary in a number of cases when the picramate method was used.

5. The intensity of the picramate color is not proportional to the amount of sugar present. Therefore a table has been compiled which gives factors to be used throughout the range of colorimeter readings.

6. The color values for 8 reducing sugars, in comparison with glucose, have been determined.

7. The necessity for strict empiricism in this method is emphasized, and the method in detail is given, involving the modifications presented in this paper.

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EFFECT OF MOISTURE ON A SEED-BORNE BEAN DISEASE[1]

LEWIS T. LEONARD

Physiologist, Soil Bacteriology Investigations, Bureau of Plant Industry, United States Department of Agriculture

INTRODUCTION

In a preliminary paper (*9*)[2] attention was called to a wilt disease of navy beans, *Phaseolus vulgaris* L., noted at Redfield, S. Dak., which seemed to arise from the application of legume bacteria culture to the seed prior to planting or to be favored by such application. Experimental work at Redfield in 1922 indicated that inoculation applied in the liquid form, or water applied in a similar manner to the progeny of the seed on whose plants the original observations were made, stimulated the disease to such an extent that it was possible to superficially differentiate the rows so treated from those untreated. It was concluded, therefore, that moisture was largely responsible for these differences: The initial stimulation afforded by this means to the disease organisms in and on the seed being sufficient to cause an appreciable effect which was in evidence practically the whole time during the vegetative period and was reflected in the harvest of beans.

Moisture is artificially applied to many legume seed by inoculation with suspensions of nitrogen-fixing legume bacteria in water or nutrient solutions. Inoculation is not ordinarily a soaking process, although soaking has been recommended for certain legume seed; it is merely a case of light moistening generally followed by drying in air or immediate sowing. When carried out in the regular manner it will be very rare that stimulation of destructive bacteria or disease organisms will be perceptible. In the great majority of cases treatment with inoculation has been so decidedly beneficial that when a case to the contrary arises it is advisable to trace it to its cause.

REVIEW OF LITERATURE

FUNDAMENTAL EFFECTS OF SEED SOAKING

The effect of moisture on seed has been studied by many investigators and the literature concerning most of the studies is covered by Kidd and West. (*8*) The outstanding earlier work has been summed up by Wollny. (*14*) His general conclusion is that the harm occasioned by soaking in water was due to the loss of necessary soluble nutrients from the seed by osmotic transfer. This condition, it was found, is encouraged especially by excess water and is influenced by the species of seed, duration of the immersion, and the temperature of the water. Hiltner (*7*) found that long continued soaking in excess water reduced the disease-resisting power of the seed, encouraged the activities of destructive bacteria, but that moisture applied in such a manner as to simulate natural conditions had a beneficial effect. Kidd and West (*8*) using bean seed presumably free from disease which had been soaked for six hours in an excess of water at temperatures of from 5 to

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[2] Reference is made by number (italic) to "Literature cited," p. 496-497.

20° C., inclusive, found that a germination test indicated no injury, but in the subsequent growth it became evident that the plants from the soaked seed were less in size and weight than an equal number of plants from untreated seed.

Braun (*1*) by soaking wheat seed for 10 minutes in water, then draining and covering them for six hours, found that the efficiency of the disinfectant used was increased, due to the stimulation of the dormant bacteria on the seed into a growing condition, in which state they are more easily destroyed and that the harmful effects of long continued soaking were thus largely obviated. In his general work on the internally borne seed disease Chen (*2*) used this same method to free the seed coats from live organisms by disinfection.

DISTINCTION BETWEEN BLIGHT AND WILT

The disease to which this paper makes especial reference is produced by *Bacterium flaccumfaciens* Hedges and has been called bean wilt. Unfortunately the earlier literature makes no distinction between the bean disease caused by this organism which was only recently isolated and named, and the bean blight by *Bact. phaseoli* Erw. Sm. The statements in this brief review of the literature will apply to either or both of the diseases and the term blight will be applied to the disease not specifically ascribed to *Bact. flaccumfaciens.* As the two diseases mentioned are very closely allied and likely to be confused, it might be well to call attention to the differences between them as recently brought out by Florence Hedges (*5*, *6*):

1. The wilt organism apparently does not produce stomatal infection as does the blight organism and is not accompanied by conspicuous yellowing of the leaves.
2. Wilt organisms resist desiccation for a much longer period (even 5 years) than that previously reported for *Bact. phaseoli.*
3. In pod infections the wilt follows the sutures whereas *Bact. phaseoli* produces spots.

FACTORS AFFECTING THE BEAN BLIGHT

With the idea of disinfection Edgerton and Moreland (*3*) treated bean seed infected with the blight organism by soaking for eight minutes in water at 50° C. They found that this treatment not only did not affect the blight organisms seriously but that the plants from the seed thus treated were more affected by the disease than the plants from the untreated seed. This anomalous condition they explained was probably due to the reduction of the vitality of the seed by the treatment, this contributing to the susceptibility of the plants to the disease. It is quite possible too that the stimulation of the seed-borne organisms occasioned by the water was an important factor. If so small an amount as is added by the process of inoculation can produce noticeable results, the moisture which naturally comes in contact with the seed must have a bearing on the development of the disease. Sackett (*12*) is of the opinion that warm wet weather favors the bean blight and Muncie (*10*) making observations in Michigan found that the disease is more widespread under wet and muggy conditions. Rapp (*11*) observed that cool wet weather does not favor the development of the disease but found that it continues to spread following warm wet weather. He considers rain and dew important factors in the transmission of the disease. Halsted (*4*) correlated an increase in bean blight to irrigation, and Sackett (*13*) thinks this is one of the factors for disseminating the disease.

THE RESULTS OF 1922

Since the harvest of seed from the 1922 experiments has not been reported hitherto, it seems advisable to give the results here (Table I) as a corroboration

of the evidence concerning the presence of wilt symptoms among the bean plants previously reported (*9*). From a practical standpoint, the amount of seed produced constitutes a better index of the effect than observations on the numbers of diseased plants.

The effect of the disease and moisture additions on the Redfield beans, it is revealed in the figures, is reflected also in the bean yields and the differences follow the same general trend that was indicated by observations on the growing beans, that is, the plants from seed treated with moisture gave a higher percentage of disease and a lower yield of seed than the plants from seed not treated with moisture.

On the other hand the clean seed shows the same correlation only in a minor degree. The plants from the selected seed acted more as a unit, all ripening their seed at approximately the same time whereas the plants from the Redfield seed ripened unevenly; at the time of harvest green beans and flowers were noticeable to the approximate extent of 10 per cent in all rows except one of those planted to untreated seed, which for some unknown reason ripened uniformly. There was evidence of the wilt among these immature beans.

Considering the average yield of 671 gm. as 100 per cent, the average reduction in crop, apparently due to the addition of moisture to the seed before planting, is 30.3 per cent, ranging from 51.3 per cent for the water treatment to 6.9 per cent reduction from treatment with bean culture No. 162.

TABLE I.—*Navy bean yields from plats at Redfield, S. Dak., in 1922*

Treatment [a]	Redfield seed [b]	Clean seed [c]
	Grams	*Grams*
None	710	809
Water	237	710
Ashby broth	525	802
Soil broth	511	767
Inoculated soil	632	824
Commercial culture	405	752
407 Wisconsin culture	469	724
342 United States Department of Agriculture culture	412	824
162 United States Department of Agriculture culture	625	767

[a] With the exception of the inoculated soil, all treatments were applied in the liquid form at the rate of approximately 10 cc. per 500 gm. of beans.
[b] Harvested Aug. 24, 1922.
[c] Harvested Aug. 10, 1922. Each figure is the average of two plats.

EXPERIMENTAL WORK IN 1923

PREPARATION AND PLANTING

The experience of 1922 led to the planning of more extensive work for 1923 under dry land, humid, and irrigated soil conditions. It was hoped to determine the conditions favorable for the development of disease in connection with inoculation with legume bacteria, the extent of these conditions, and additional proof of the efficacy of the measures for control.

The seed employed in the major portion of the experiments were progeny of the Redfield seed used in the former experiment. At Mandan, N. Dak., and Rosslyn, Va., a badly diseased mixture of commercial bean seed was used. Seed of Robust bean, cowpeas, and tepary beans were also planted with the idea of establishing the presence of disease amongst them and the stimulation of such disease if present by the addition of moisture. At each place the beans were planted in equal length rows, but owing to variations in the sizes of plots at the different places, the rows of the different plots are not comparable. As far as possible, rows were made equivalent to one four-hundredth of an acre. Each of the treatments given below was duplicated at each place.

No.	Treatment
1	Liquid pure culture applied as usual.[3]
2	No treatment.
3	Liquid pure culture applied in excess and allowed to stand one hour before spreading out to dry.
4	Dry soil applied by the glue method.[4]
5	Dry soil applied by the glue method dried 10 days previous to planting.
6	Liquid pure culture applied as usual, dried 10 days before planting.
7	Dry soil applied by sowing in rows with seed.
8	Liquid pure culture applied as usual dried 24 hours before planting.
9	No treatment.
10	Liquid pure culture applied as usual.

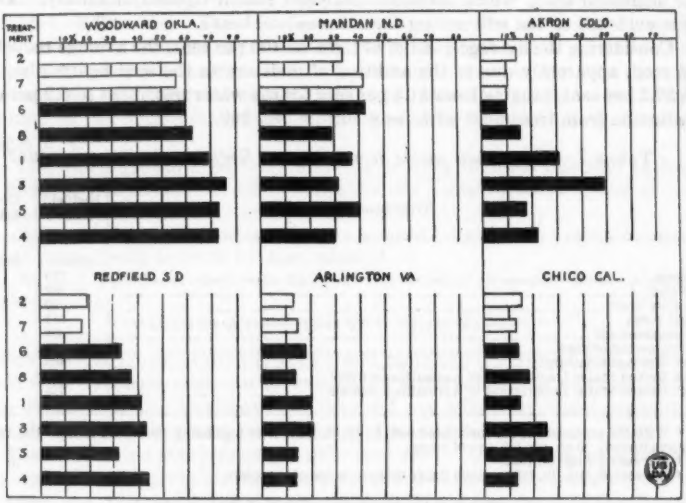

FIG. 1.—Chart showing percentage of observed wilt disease symptoms among navy beans under the different treatments. Entirely black bars represent the moisture treated rows

The same plan of experiment was conducted at the Great Plains stations of the Office of Dry Land Agriculture at Mandan, N. Dak.; Akron, Colo.; Woodward, Okla.; and at the station of the Office of Forage Crop Investigations, Redfield, S. Dak. It was conducted under irrigated soil conditions at the farm of the Office of Foreign Seed and Plant Introduction at Chico, Calif., and under humid conditions at the Arlington Experiment Farm of the United States Department of Agriculture at Rosslyn, Va., and on private ground at Leeland, Montgomery County, Md. Conditions at these places are indicated in Table II.

[3] Liquid pure culture was applied at the approximate rate of 10 cc. per 500 gm. of bean seed, mixed with the seed by hand and at once spread out to dry. The excess application was made similarly with double the quantity of liquid, with the exception that the seed were covered with paper one hour before being spread out to dry.

[4] A 5 per cent glue solution is prepared by adding furniture glue to boiling water and cooling. The seed are moistened with this mixture and dry infected soil sifted over them to absorb the moisture and adhere to the seed coats.

PRESENCE OF WILT SYMPTOMS

Observations were made on the experiments by counting all of the plants in a row and also the plants which gave evidence of wilt disease symptoms or were dead either on account of drought, injury, or other disease.

The effect of drought on the mortality among the beans at Woodward, Okla., is shown in Figure 1. If we consider this a constant factor the results may still have a meaning as regards the effect of the combination of moisture and disease.

TABLE II.—*Soil types, initial moisture and dates of planting beans at the various places of experiment*

Place of experiment	Type of soil	Initial moisture[a]	Date of planting	Date of observation
		Per cent		
Arlington, Va.	Clay loam	11	June 15, 1923	Sept. 10, 1923
Akron, Colo.	Light sandy loam	10.7	May 18, 1923	Aug. 4, 1923
Chico, Calif.	Sandy loam	7.9	May 3, 1923	Aug. 10, 1923
Leeland, Md.	Chester loam	6.4	June 26, 1923	
Mandan, N. Dak.	Black sandy loam	2.8	May 23, 1923	Aug. 21, 1923
Redfield, S. Dak.	Black clay loam	7.9	May 26, 1923	Aug. 24, 1923
Woodward, Okla.	Canadian sandy loam	4.9	May 12, 1923	Aug. 1, 1923

[a] Determinations made by Franklin W. Marsh of the Office of Soil Bacteriology, United States Department of Agriculture

At Redfield and Woodward, there is a consistent increase in the amount of disease corresponding to increasing applications of moisture. Excluding the data from Mandan there is a general indication of the same result at all other places but it is less striking than at Woodward and Redfield. Nodules were present on roots at all places.

Among the other legumes used only the Robust beans showed occasional symptoms of the wilt.

SEED HARVEST

The seed were harvested at all places except Woodward and Akron. They were examined for the presence of diseased and abnormal seed. The figures in Table III give in detail the yields from the various places together with the results of the pickage.

The average of the effect of the moisture treatments are compared with the control and dry treatments in Figure 2. These are shown together. It is significant that in each case the crops from the seed planted dry exceed those of the moisture treatments.

DISCUSSION

EFFECT OF RAINFALL AND TEMPERATURE

To determine whether a correlation existed between the extent of the disease and the rainfall a study has been made of the records from Redfield and other places at which the experiments were made. (fig. 3).

To give an idea of the condition of the soil at Redfield as regards moisture, rainfall prior to planting has been considered. The period covered following the planting is the approximate time of vegetative growth for navy beans. If we consider the first three years only, it will be noticed that in 1920, when the damage was the greatest, the rainfall was also excessive, but if the record of 1923, also a rainy year, is included this deduction is vitiated by the fact that the damage in this year can not be considered excessive.

A review of the rainfall data in 1923 at the various places where the experiments were made does not indicate great differences in total or periodical rainfall between the dry-land and humid sections. At Chico, Calif., the rainfall was slight, but it was supplemented by irrigation at six different times during the season. There seems to be no correlation between the moisture in the soil at planting time and the subsequent amount of disease.

If the temperatures of 1920 and 1923 at Redfield are compared (fig. 4) it is found that when the plantings were made, there was a difference of 8°, 1923 having the higher temperature. Throughout the growing period there was a rather regular alternation of high and low temperatures during both years. The rise and fall periods were approximately 10 days in length and were quite noticeable for the first 50 days. The mean daily temperature of 1920 for the period is 67¼° F., whereas that for 1923 is 70¾° F. Taking temperature, moisture, and the observations of previous investigations into consideration, it was reasonable to expect that the damage among the beans would be greater in 1923.

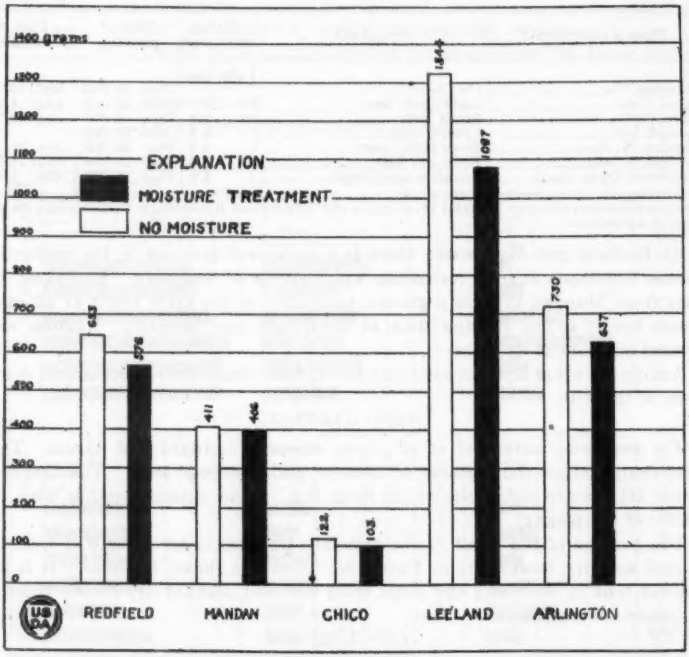

FIG. 2.—Chart showing graphically the average differences in yield in grams between the moisture and no moisture treatment

Such, however, was not the case. It is probable, therefore, that moisture added to the seed before planting is a more potent factor in the stimulation of the bean disease than the natural conditions which obtain during the life of the plant.

TABLE III.—*Seed yields, in grams, from 1923 bean plots*

Treatment	Redfield, S. Dak.			Mandan, N. Dak.			Chico, Calif.			Leeland, Md.			Arlington, Va.		
	Total yield	Clean seed	Per cent diseased	Total yield	Clean seed	Per cent diseased	Total yield	Clean seed	Per cent diseased	Total yield	Clean seed	Per cent diseased	Total yield	Clean seed	Per cent diseased
None	622	543	12.7	440	391	11.2	137	128	6.6	1,362	1,073	21.2	704	534	24.2
1	512	422	17.6	462	422	8.7	81	76	6.2	982	775	21.1	641	550	14.2
3	481	402	16.4	445	405	9.0	111	109	1.8	1,098	852	22.4	563	453	19.6
6	729	604	17.1	277	244	11.9	120	106	11.7	1,113	906	18.6	761	601	21.0
8	637	480	24.7	372	338	9.2	71	64	9.9	1,217	1,023	16.0	720	559	22.4
7	684	604	11.7	382	352	7.9	107	98	8.4	1,326	1,091	17.8	757	580	23.4
4	436	384	12.0	511	461	9.8	106	100	5.7	1,050	880	16.2	558	428	23.3
5	662	529	20.1	370	322	13.0	130	125	3.9	1,124	907	19.3	580	479	17.4

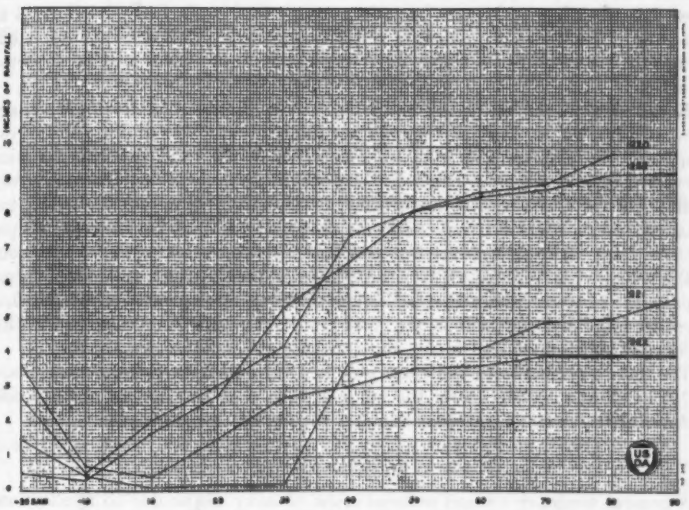

FIG. 3.—Graph showing accumulative rainfall data from 20 days prior to planting to 90 days after planting for four years at Redfield, S. Dak.

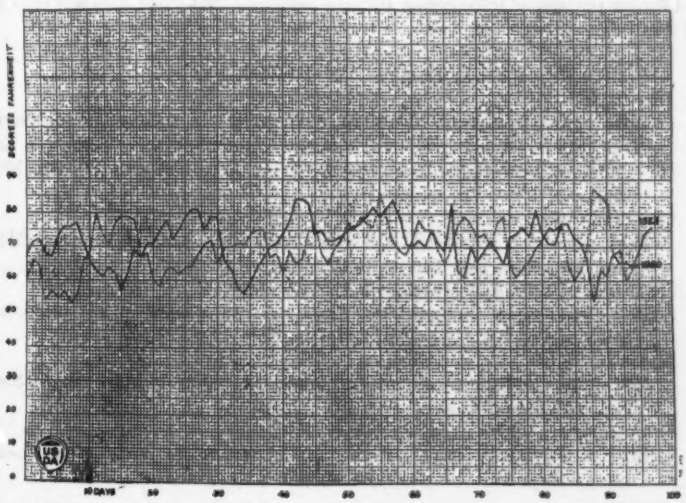

FIG. 4.—Graph showing mean daily temperatures from the time of planting at Redfield, S. Dak., for the years 1920 and 1923

ECONOMIC ASPECT

Observations made on legume inoculation experiments in different parts of the United States over a period of 20 years have shown that only in extremely rare cases has the effect of legume bacteria cultures been apparently detrimental to the crop. The intent of this paper is not to emphasize an imminent danger but to record the possibilities which may under certain circumstances be expected to arise.

Recalling that the estimated loss from wilt at Redfield in 1920 was 90 per cent; in 1921, 25 per cent; in 1922, 30 per cent; in 1923, 12 per cent; and of the crop that the average loss from all places where the bean experiments were harvested in 1923 was approximately 11 per cent, that the Plant Disease Survey Bulletin of the United States Department of Agriculture gives for the loss to the total crop from blight for three years starting with 1920, as 1.5 per cent, 9.8 per cent, and 4.9 per cent, respectively, and that Muncie estimates that 30 per cent of the bean pickage is infected with the blight, the possibilities for damage become apparent. It seems reasonable to assume that the same general effect that has been produced by bean wilt in the work under discussion may also occur with other seed borne diseases.

The data obtained from the clean seed in 1922 and from clean Robust beans in 1923 indicates rather clearly the value of such seed for planting and the correctness of the common recommendations for its use.

SUMMARY

A general tendency toward reduced crops of navy beans, due to applications of moisture to seed presumably harboring *Bact. flaccumfaciens*, prior to planting, is indicated by the harvests from the various places of experiment.

Dry soil as inoculating material will obviate the necessity for moistening the seed for the purpose of introducing *Bacillus radicicola* and clean seed will tend to cut down losses even when moisture is applied.

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